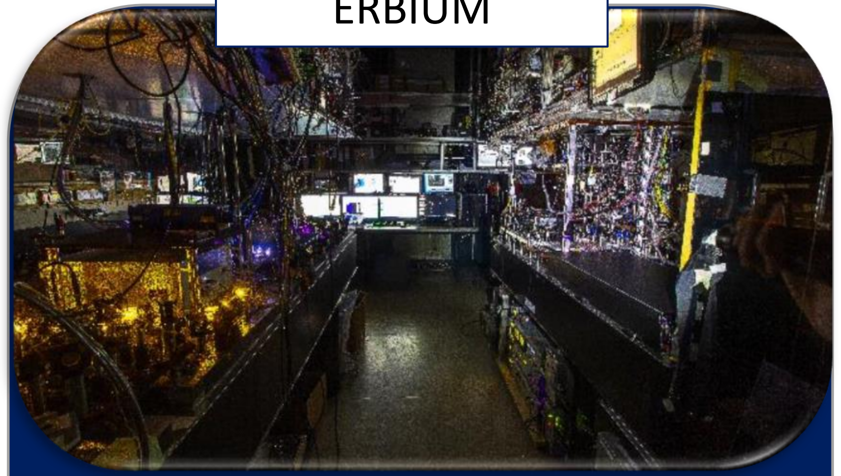
Dipolar Quantum Gases

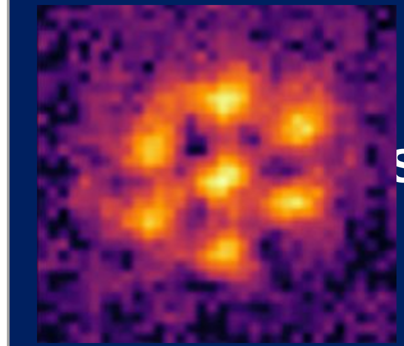
WWW.ERBIUM.AT

Institute for Experimental Physics and IQOQI

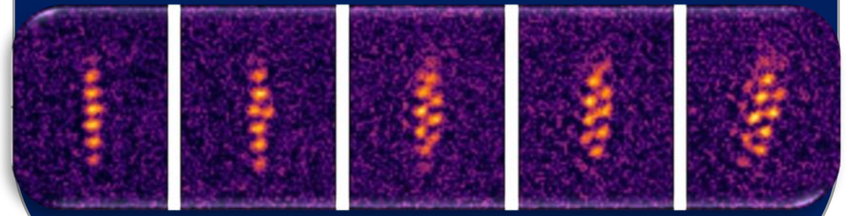
Theory Experiments

ERBIUM

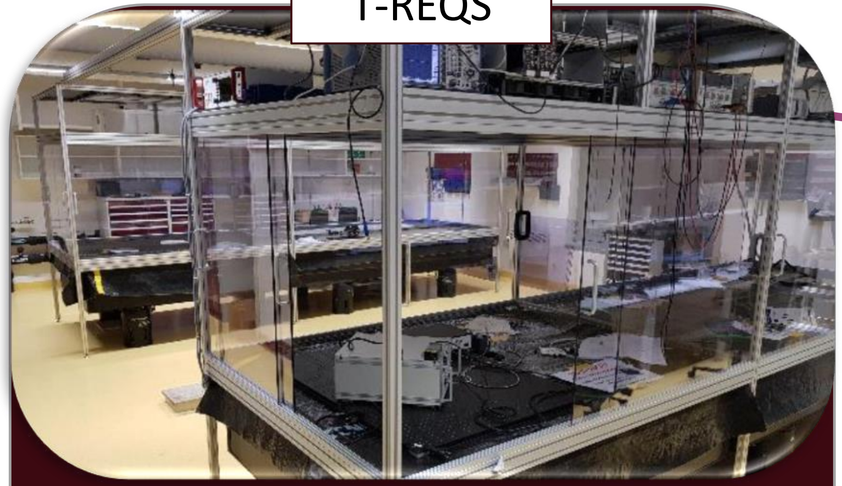




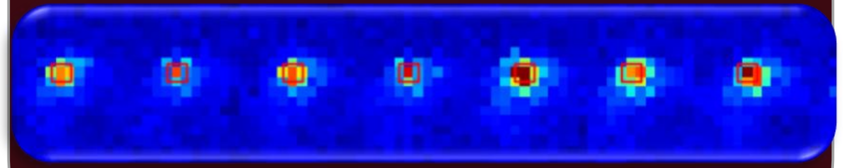
The discover of Supersolidity and Bloch Oscillations



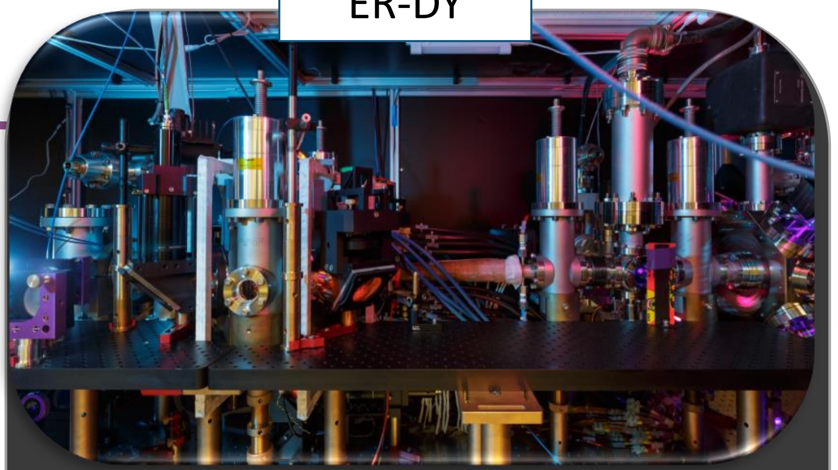
T-REQS

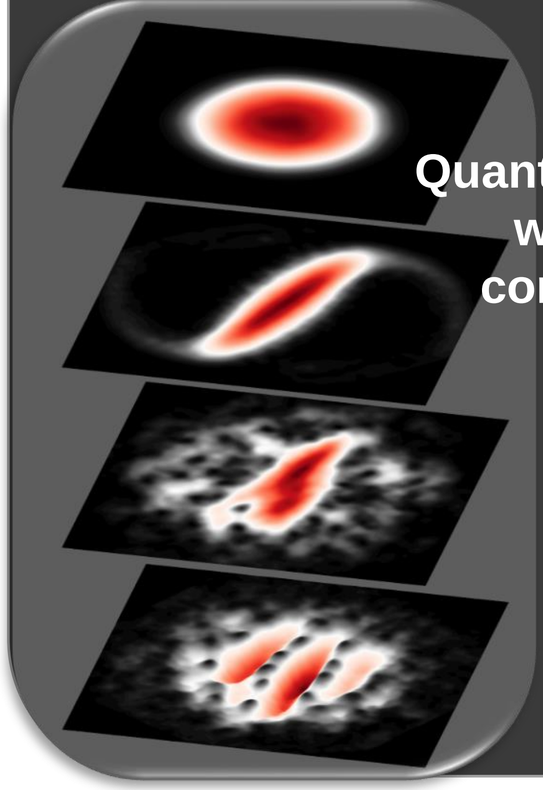


Single atomic magnet in an array of tweezers for quantum info



ER-DY

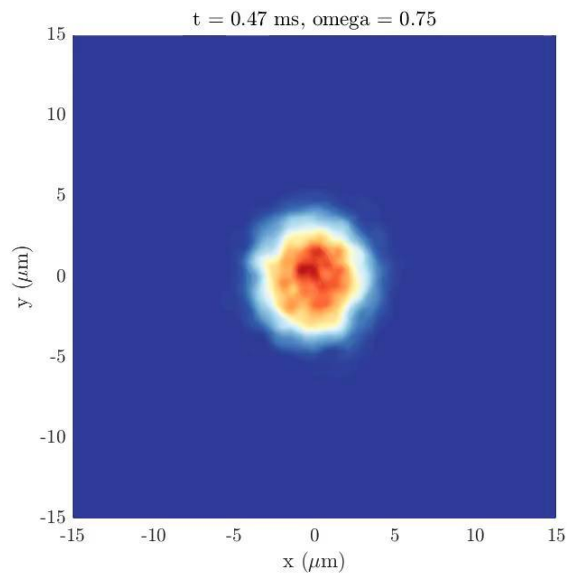




Quantum Vortices with high connectivity

Theory

Simulation of the behavior of dipolar quantum



Dipolar Quantum Gases

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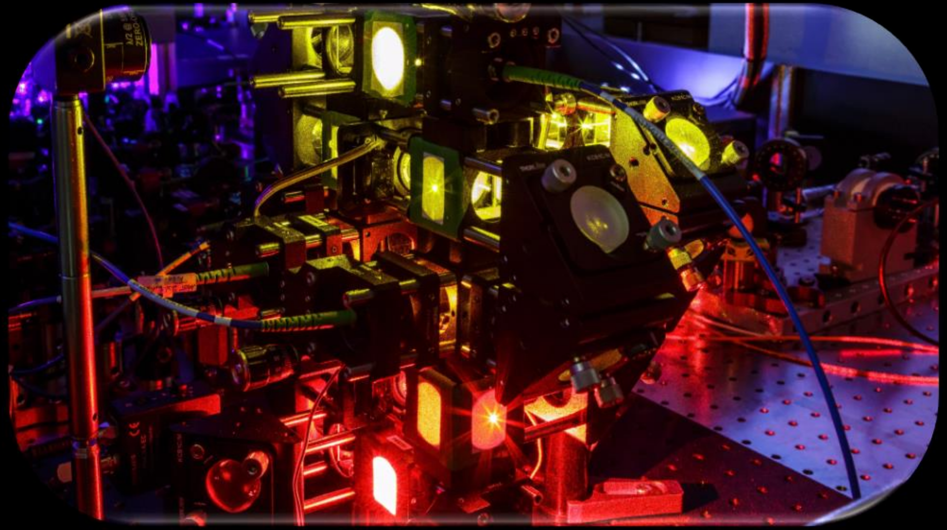
The Team

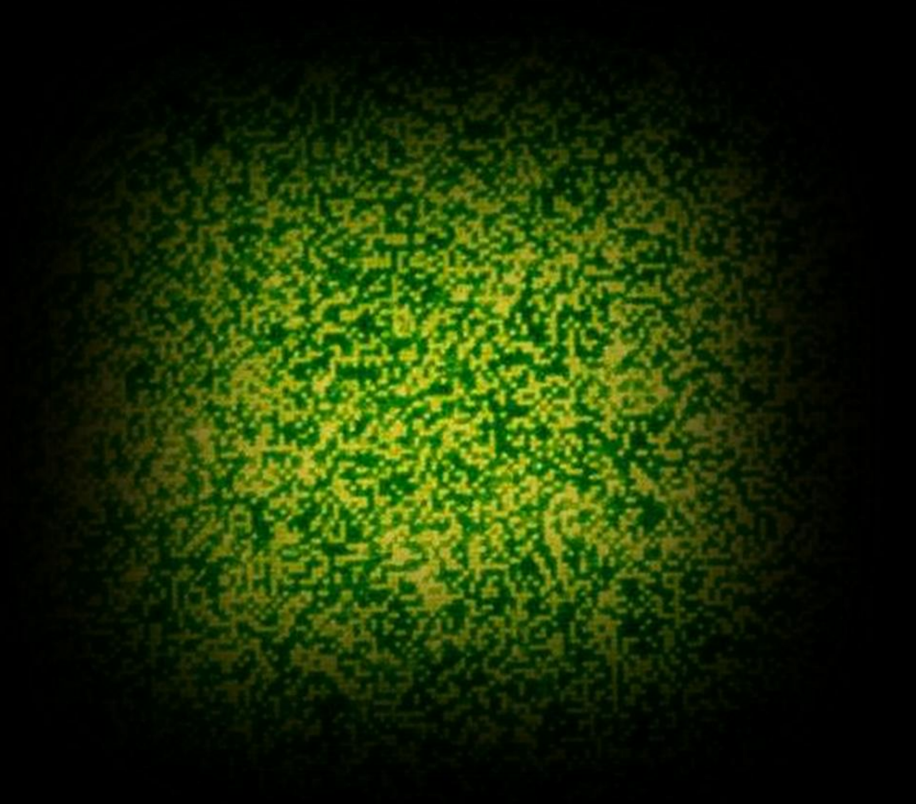
Group Leader:
Univ. Prof. Dr. Francesca Ferlaino

universität innsbruck

ÖAW IQI

Senior Scientist:
Dr. Manfred Mark





Experimental *Theory* *Theory*

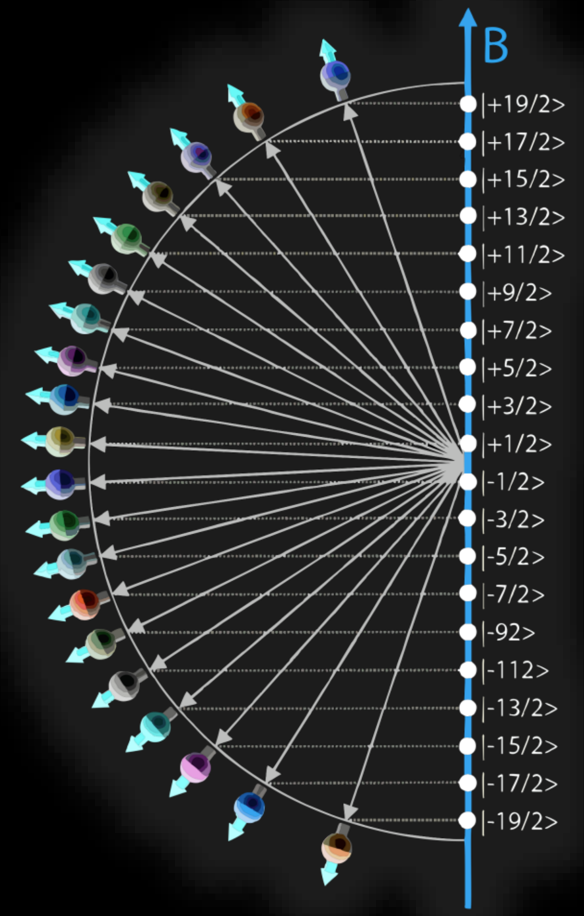
Bachelor & Master Projects

Experimental

With optional laborpraktikum:

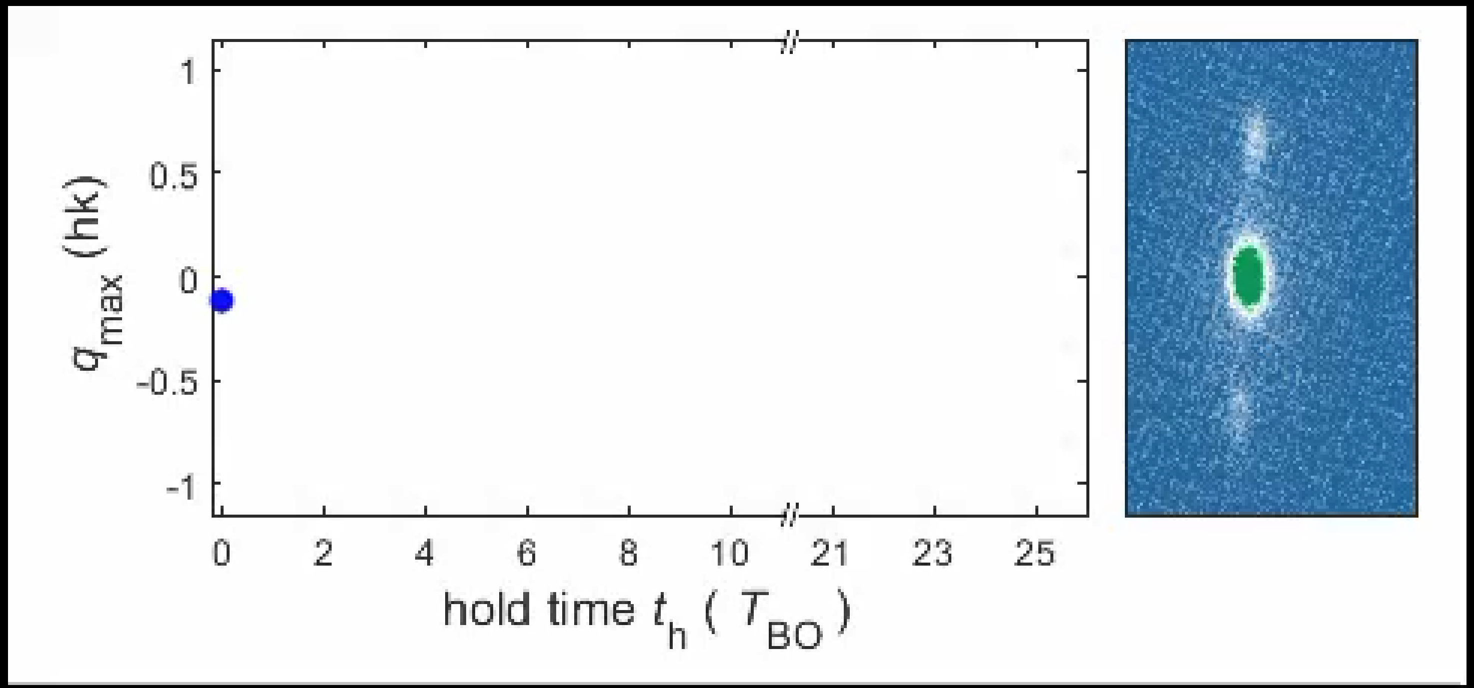
704461 PR Spezielles Laborpraktikum B: Optik (PR / 2h / 5 ETCS-AP)

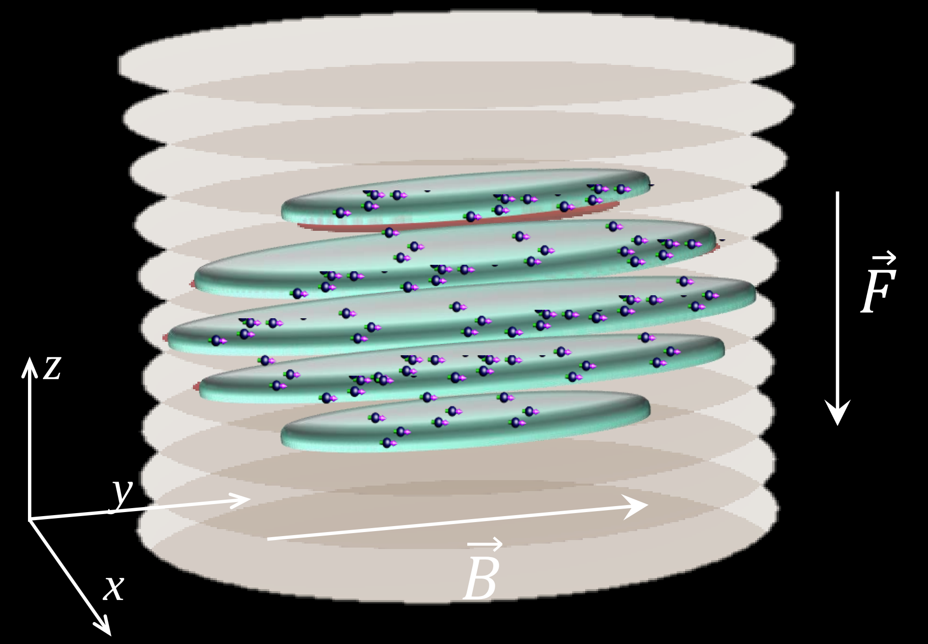
3-4 weeks (5 pages in BA Thesis)



1. Bloch oscillations: Atom Interferometry

Bachelor Project (**Experimental**)





Topic:

In a crystal of light, particles subjected to a force will oscillate forever in momentum space. The frequency of such Bloch oscillations is one of the most accurate interferometric methods to measure small forces, ranging from the gravitational force down to quantum phenomena like the Casimir–Polder force.

In the lab (optional internship):

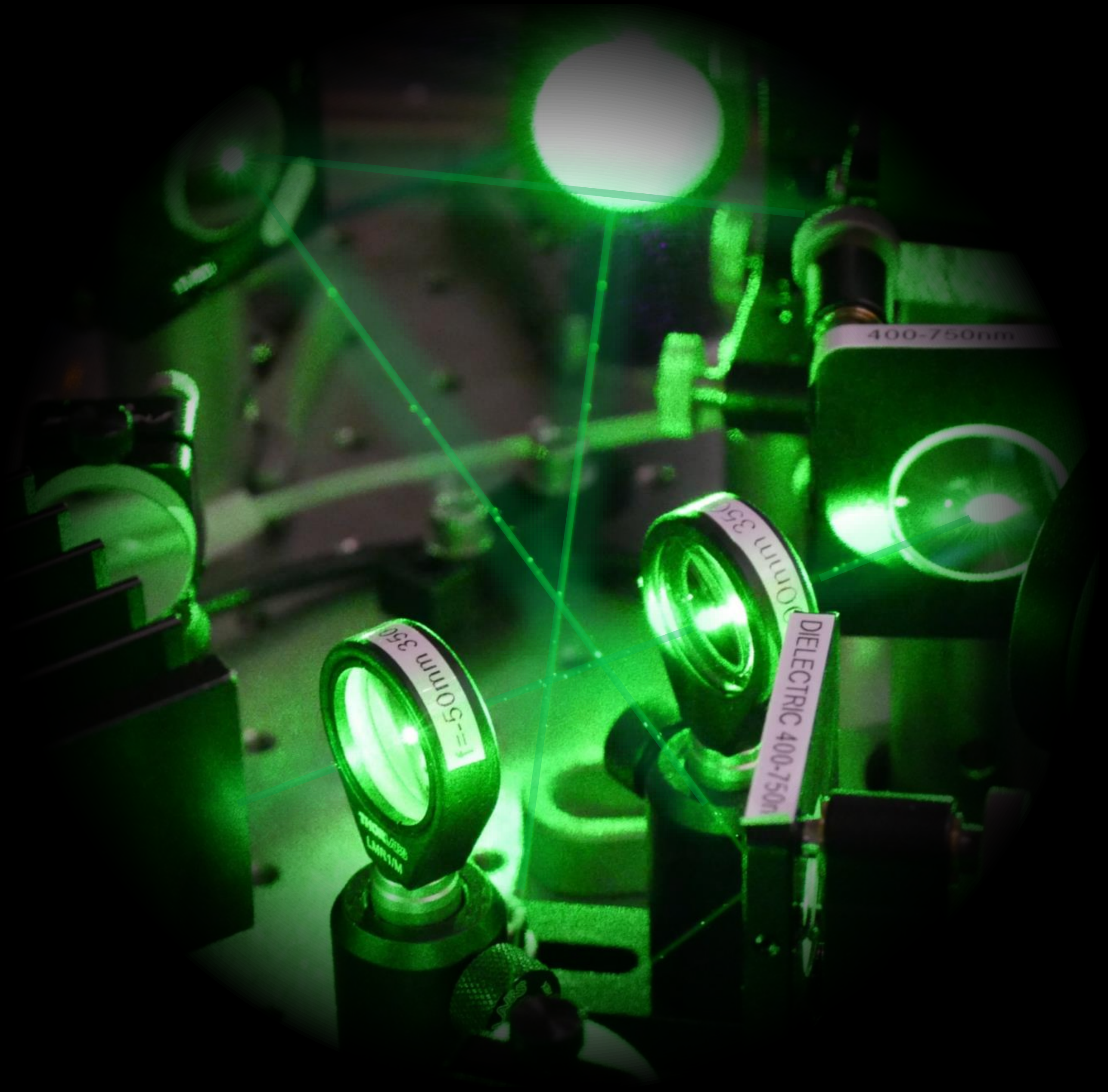
Participate in building yourself a crystal of light and in stabilizing it.

More: When a force acts upon a particle it is accelerated and gains momentum. Particles in a crystal however are confined in momentum-space to the band structure of the crystal. When the force is small enough to prevent the particle to jump to a different band, the particle experience a sudden jump in momentum space when it reaches the end of the Brillouin zone. In an ideal crystal and under a constant force, the particle will oscillate indefinitely. The frequency and the damping of these Bloch oscillations are very sensitive to changes in the force, crystal or environment of the system. Bloch oscillations can therefore be used as a sensitive tool to measure a host of different quantities such as the local gravity field, the fine structure constant or the beyond mean-field corrections to the Gross-Pitaevskii equation.

This bachelor thesis should work out the basic description of quantum Bose gases in a lattice and the mechanism of Bloch oscillations and compare it to Bloch oscillations in solid state systems.

2. Anisotropic polarizability of multi-electron atoms: Beyond the two-level system

Bachelor Project (**Experimental**)



Topic:

Light is the key tool to manipulate, cool, trap particles. New opportunities have recently open up using the special directional dependence that some exotic atoms posses in their way to interact with light.

In the lab (optional internship):

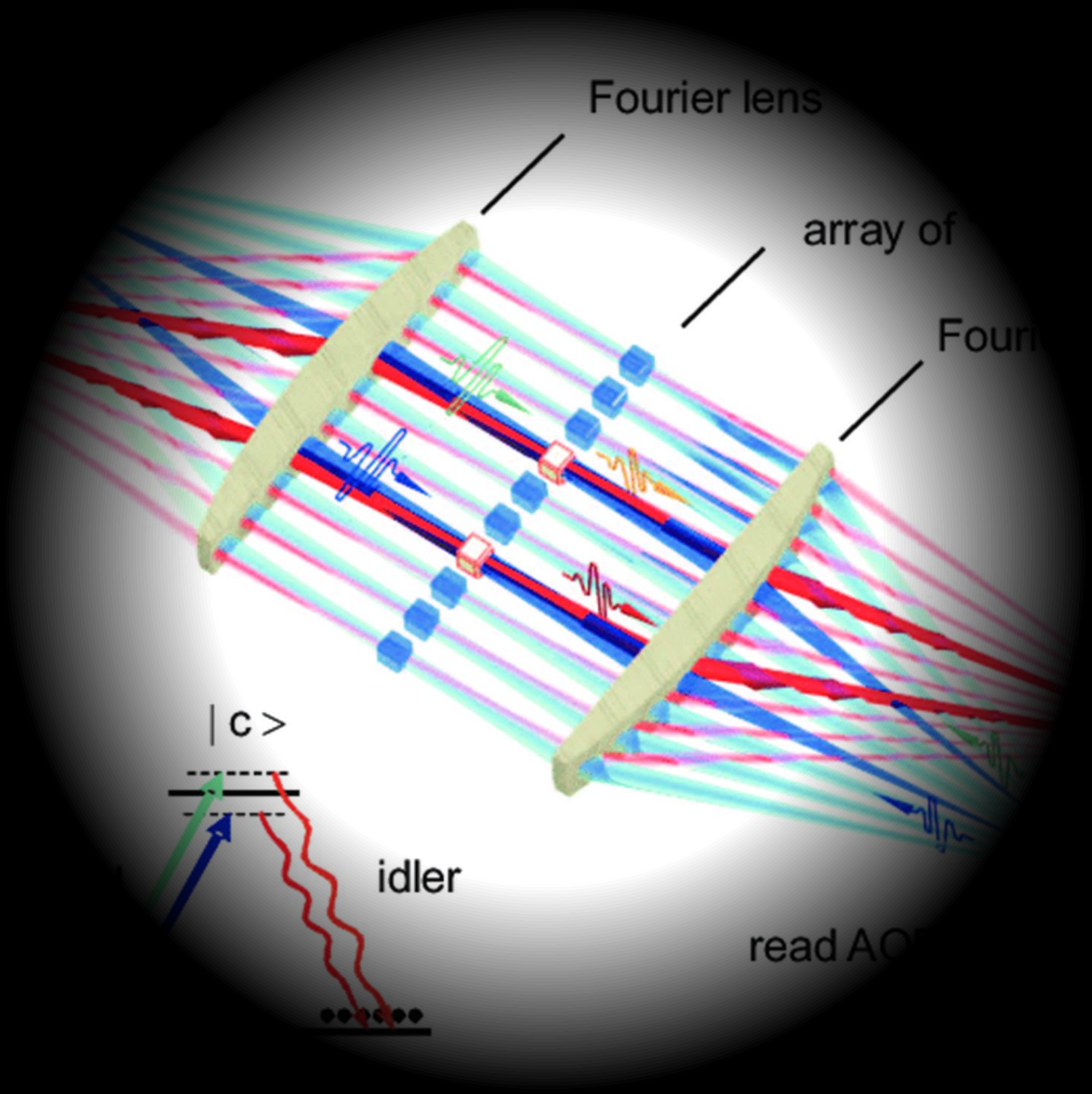
Setup and test dynamic control of polarization by the means of a Polarization rotator.

More: In many ultracold gas experiments the cooling, trapping and manipulation of the atoms is done with coherent laser light. The atom-light interaction is hereby crucially influenced by the polarization of the light: It defines the allowed transitions for resonant interactions and the depth of the dipole trap. Therefore a good control over the polarization is important. A modern development is the use of Liquid Crystal polarization rotators, which allow for an accurate and dynamic control of the polarization by.

The Bachelorarbeit should work out the basic principle of trapping atoms in far-detuned optical traps and the dependence of the polarizability on the polarization of the laser light, the working principle of Liquid Crystal optical and implementations of dynamic polarization control in ultracold atom experiments.

3. An optical quantum memory based on optical tweezers

Bachelor Project (**Experimental**)



Topic:

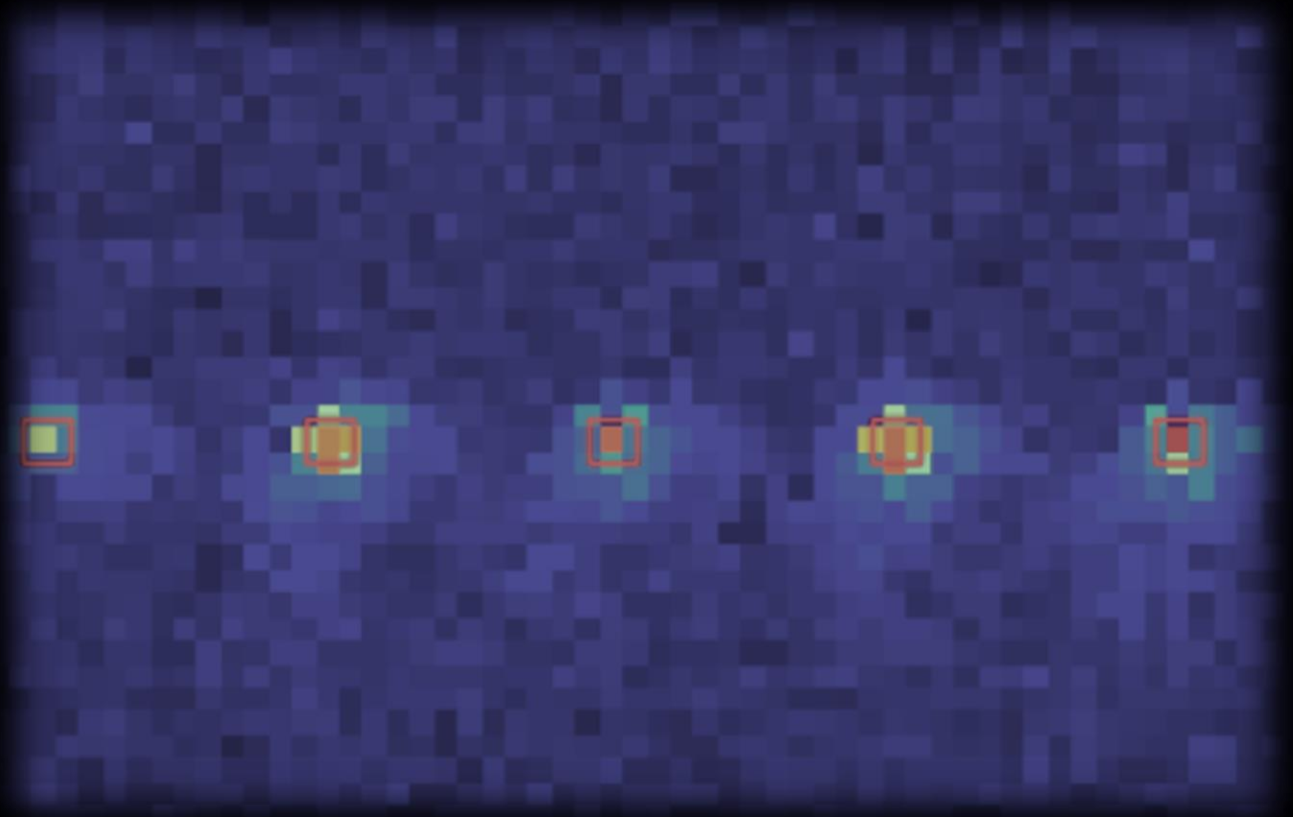
Qubits are the basic building block for quantum information and quantum computation. A flexible memory to store and retrieve qubits will allow to build quantum networks, enhance quantum communication and distributed quantum computation.

More: Quantum memories are devices capable of storing a quantum state, and are being developed in various platforms to enhance the security of communication networks and for quantum computing. In particular, light qubits can be stored in atomic systems by being absorbed using an atomic transition, transferred into a stable internal state of the atoms, and read out again as light through a coherent emission.

This thesis aims at investigating the possibility of implementing an optical quantum memory protocol for a system composed of a few atoms, spatially distributed in a controlled way by means of arrays of optical dipole traps.

4. Rydberg interactions in controlled micro-ensembles

Bachelor Project (**Experimental**)



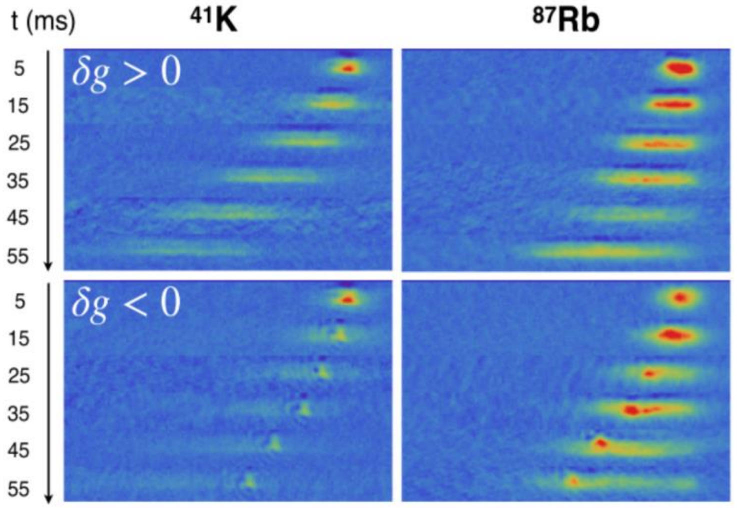
Topic:

Rydberg atoms are highly excited atoms with interesting properties for quantum computing and simulation due to their strong Rydberg-Rydberg interactions, especially when brought into configurable arrays of optical tweezers.

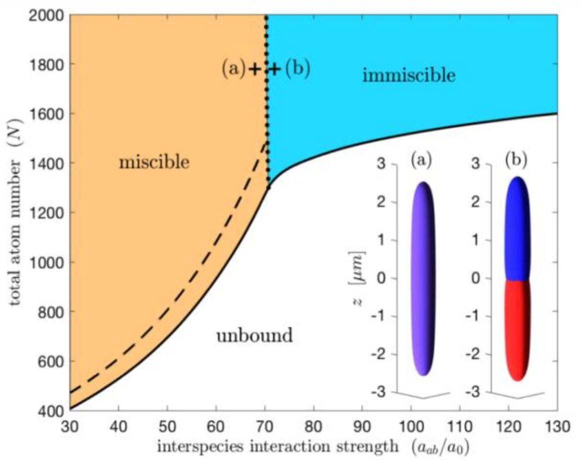
More: Rydberg atoms are high energy atoms with interesting properties for quantum computing and simulation, in particular the stronger interactions they can produce. Rydberg atoms are employed both in ensembles of millions of atoms and in arrays of single atoms in optical tweezers. When in tweezers, the single atoms can be selectively excited to Rydberg states and allow a high degree of control of the state of the system, while ensemble-based platforms make use of the effect of the strong field generated by a few Rydberg atoms on all other atoms that are kept on a ground state.

This thesis will focus on the study of a hybrid system composed of arrays of ensembles with few atoms and the effects arising from Rydberg excitations. This could bring new ideas for applications exploiting the combined properties of atomic ensembles and the high level of control of arrays of dipole traps.

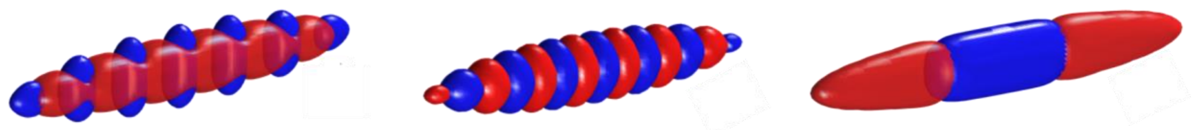
5. Many-body quantum phases in ultracold mixtures: from quantum droplets to alternating-domain supersolids



Phys. Rev. Research 1, 033155 (2019)



Phis. Rev. Lett. 126, 025301 (2021)



Phys. Rev. A 106, 053322 (2022)

Bachelor Project (**Theory**)

Topic:

Binary mixtures of Bose-Einstein condensates are a fruitful platform to study many-body quantum phases arising from the interplay between the two components. In the case of dipolar components new effects because of the long-range and anisotropic nature of the interactions come into play.

Simulating quantum gases (optional internship):

Performing numerical simulations to benchmark the theoretical predictions.

More: Binary mixtures of Bose-Einstein condensates are a platform to explore different many-body quantum phases, arising as a result of the interplay of the interactions between the two components. By tuning the inter-species and intra-species interactions, the two quantum fluids can be in a miscible or immiscible phase, and for a specific choice of interaction parameters the ground state of the system can create a self-bound quantum droplet, stabilized by quantum fluctuations. In dipolar systems the additional long-range anisotropic interaction leads to new regimes in which the two components develop a spontaneous density modulation maintaining the global phase coherence, resulting in a supersolid state.

This Bachelorarbeit should work out the basic theoretical mean-field description of quantum mixtures of bosonic alkali and dipolar lanthanide gases, including their different regimes and their properties.

Contact Us

first come, first served

francesca.ferlaino@uibk.ac.at

manfred.mark@uibk.ac.at

Bachelor Projects

1. Bloch oscillations: Atom Interferometry
2. AC-polarizability of multi-electron atoms: Beyond the two-level system
3. An optical quantum memory based on optical tweezers
4. Rydberg interactions in controlled micro-ensembles
5. Many-body quantum phases in ultracold mixtures: from quantum droplets to alternating-domain supersolids (Theory)

Master Projects

1. Quantized vortices in two-dimensional dipolar mixtures (Theory)
2. Tunable 2D lattice for quantum gas microscopy at 532nm
3. Build-up and implementation of a narrow-line laser cooling system at 631nm
4. Electric field control for the detection of Rydberg atoms
5. Build-up and testing of a new setup for ultracold atomic experiments

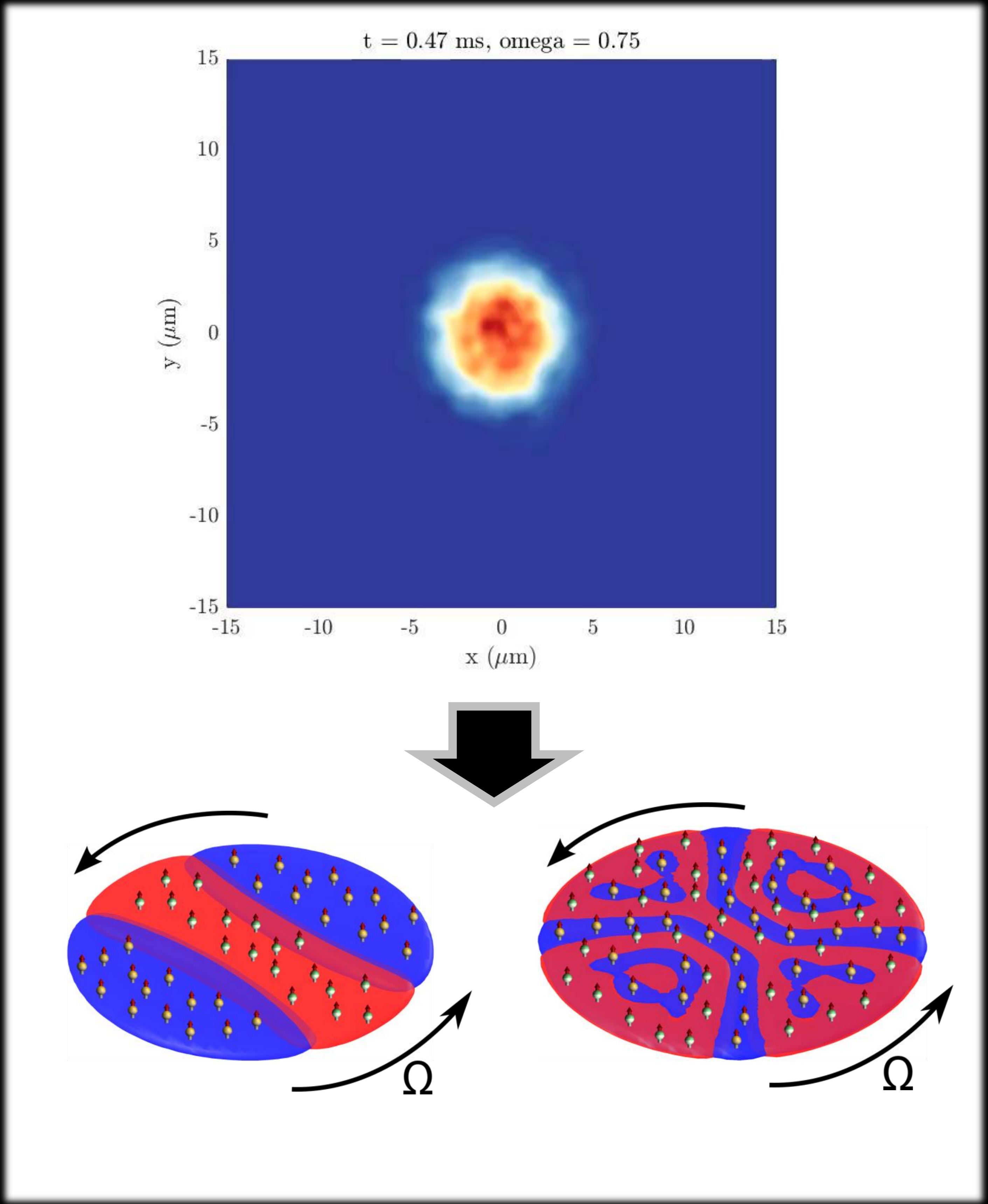
Master Project

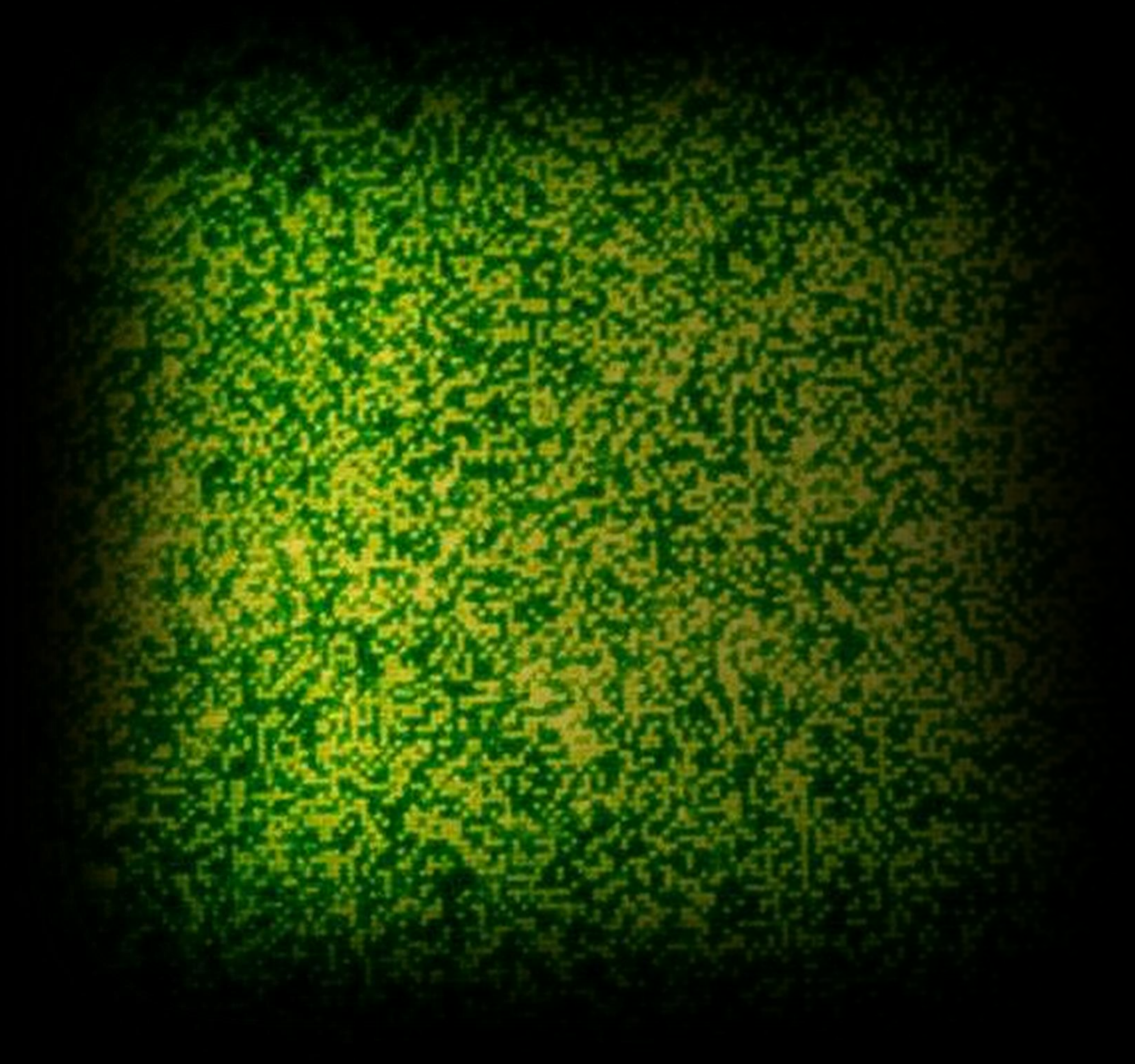
1. Quantized vortices in two-dimensional dipolar mixtures

Quantum gases of ultracold neutral atoms offer a unique platform to study phenomena like Bose-Einstein condensation (BEC), superfluidity and so-called quantized vortex nucleation. In recent years, there has been a growing interest in studying two-component quantum fluids. Here, miscible and immiscible regimes of the two components due to relative strength of inter-species and intra-species interactions open the possibility to investigate different phases. Dipolar mixtures, where atoms interact with long-range anisotropic interactions, offer even more phases including the possibility to develop a spontaneous density modulation.

You will learn:

- How to perform numerical simulations with extended Gross-Pitaevskii equation.
- How to simulate the dynamics of a rotating dipolar BEC.
- Properties of dipolar mixtures and vortices.





Master Project

2. Tunable 2D lattice for quantum gas microscopy at 532nm

This project aims to improve on our existing experiments by adding a 2D lattice with tunable periodicity using the “accordion” technique. In particular, the student will use an exisiting off-resonant laser at 532nm to build and implement an optical setup to create these tunable lattices.

You will learn:

- 2D Lattice physics
- How to build a stable optical setup
- Electronic control and stabilization

Master Project

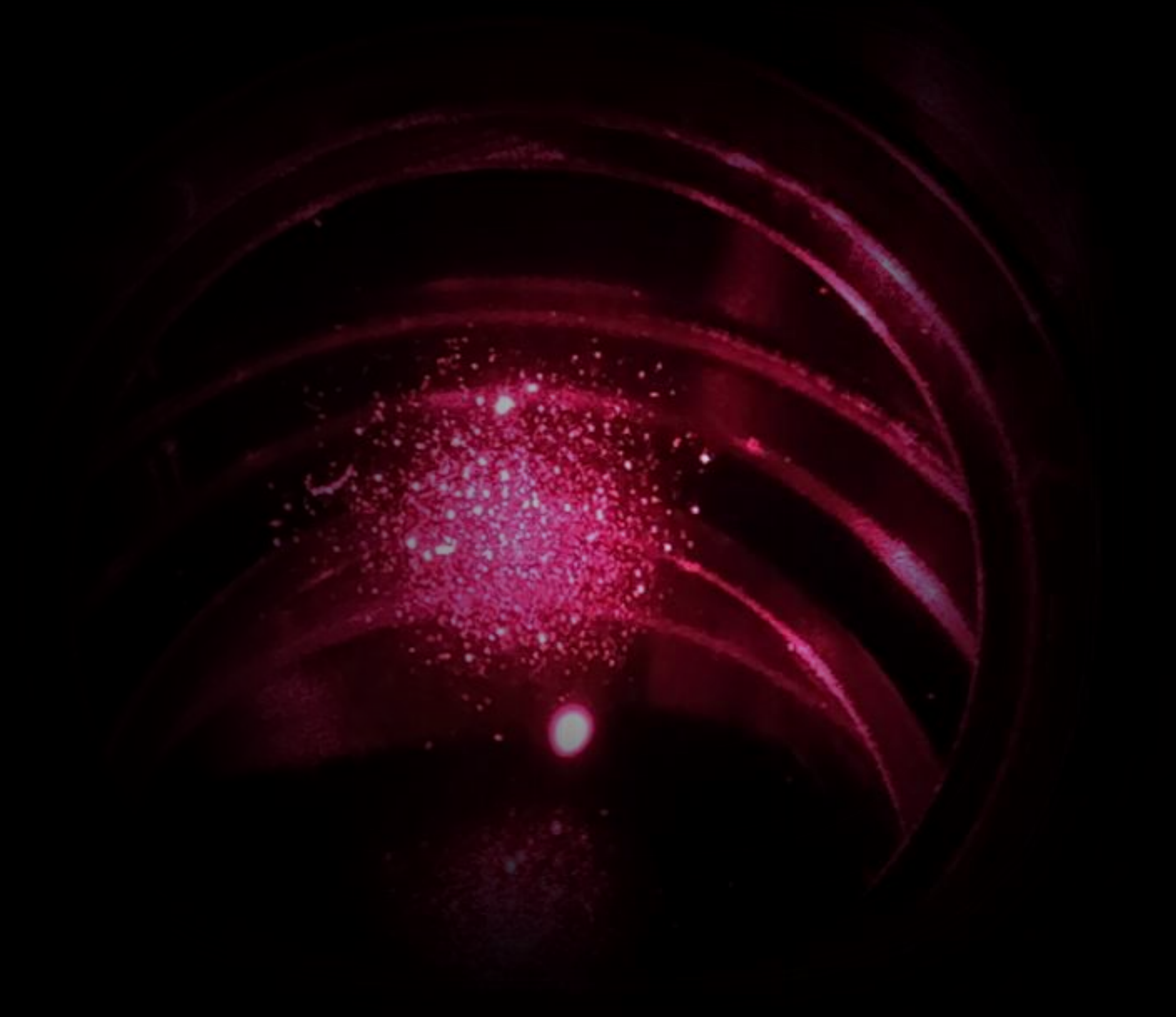
3. Build-up and implementation of a narrow-line laser cooling system at 631nm

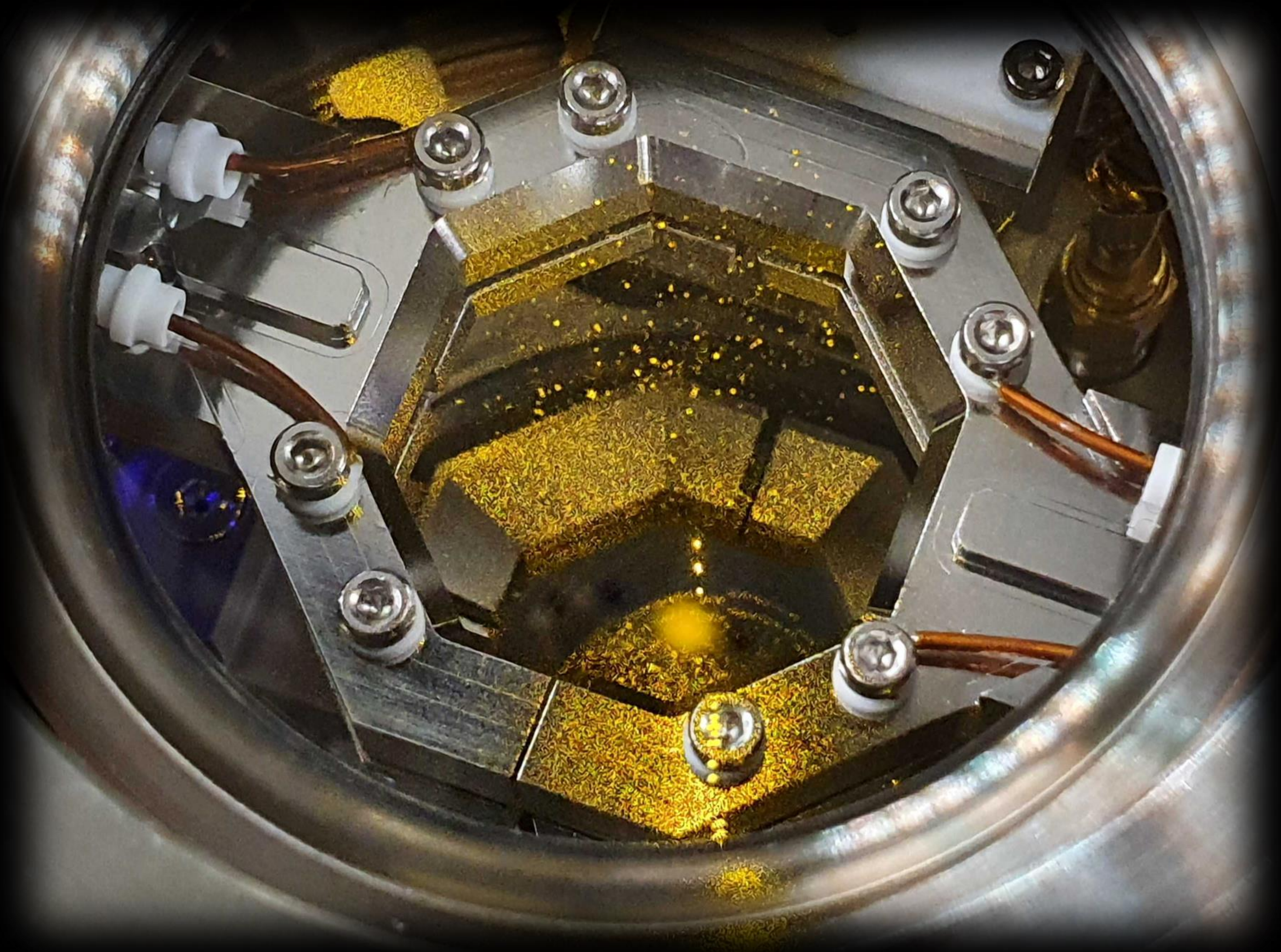
This project aims to improve on our existing experiments by adding an extra stage in the process of cooling atoms, needed for faster generation of degenerate quantum gases.

In particular, the student will control a homebuilt laser, lock it to a cavity and distribute the light to the running experiment.

You will:

- Learn cavity & laser physics
- Build an optical setup
- Learn electronic control & stabilisation
- Contribute to a running experiment





Master Project

4. Electric field control for the detection of Rydberg atoms

The goal of this project is to create a setup for the control of electric fields in the context of manipulation and detection of Rydberg atoms and ions. The setup will then be integrated with the main experiment on erbium atoms in arrays of optical tweezers.

You will learn:

- How to design and build a setup for the manipulation of electric fields
- Electronic control of equipment
- Physics of Rydberg atoms in fields

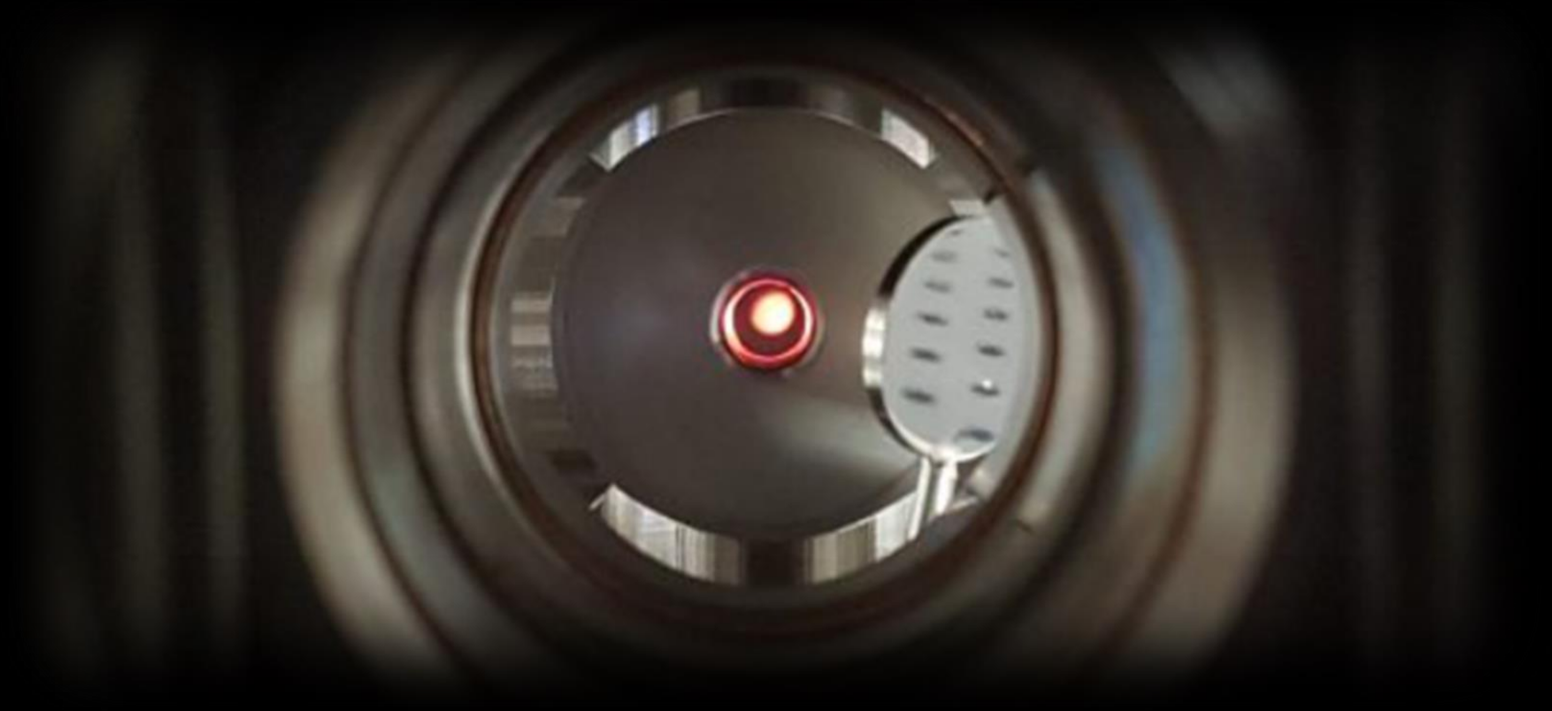
Master Project

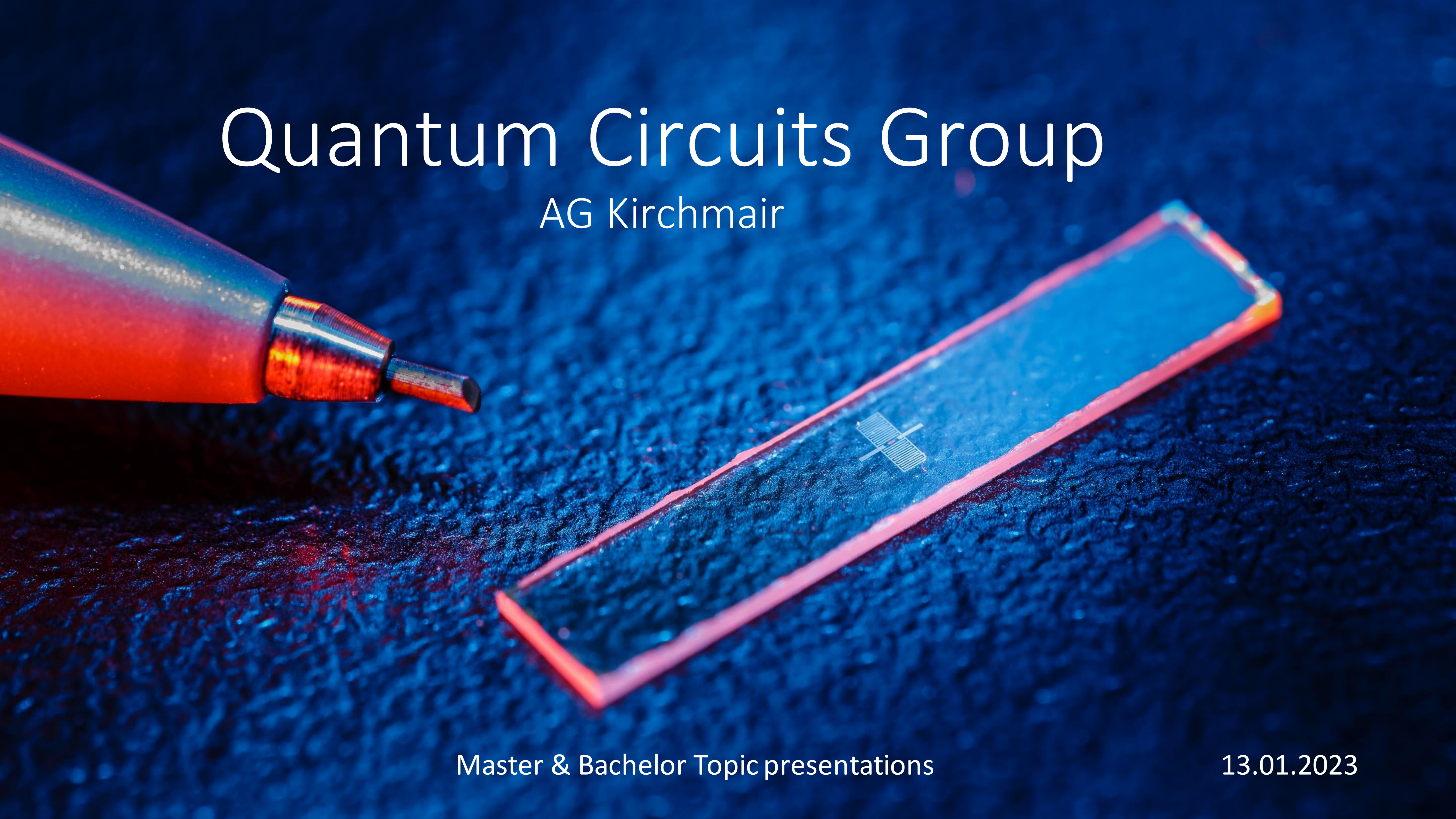
5. Build-up and testing of a new setup for ultracold atomic experiments

This project aims at the build up of a new test platform for phyisical effects and techincal improvements that would be later applied to our main experiment on erbium atoms in optical tweezers. The setup will require first to build a new vacuum chamber and an atomic beam source, including all related electronics for its monitoring and control. Later, optical setups for cooling and imaging of the atoms will be implemented, followed by the implementation of optical cooling and trapping.

You will learn:

- How to build an ultra-high vacuum system
- How to set up laser systems and optical elements for the manipulation of light beams
- Physics of optical atomic cooling, atomic control and imaging





Quantum Circuits Group

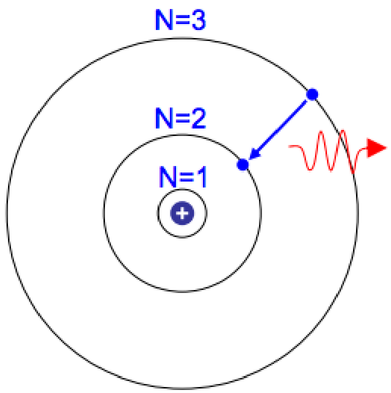
AG Kirchmair

Master & Bachelor Topic presentations

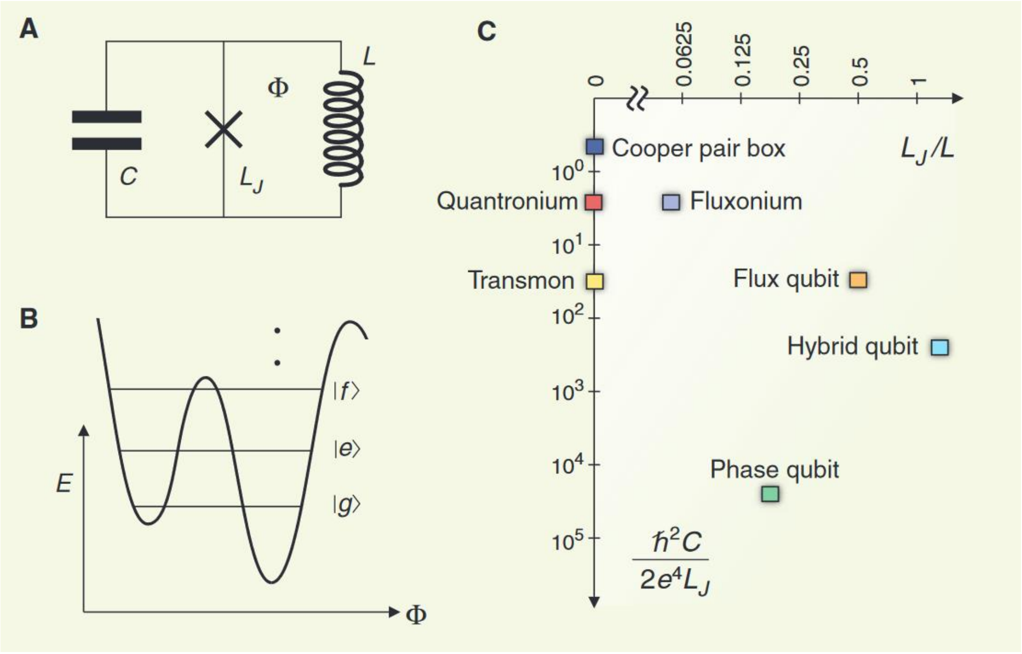
13.01.2023

Encoding of quantum bits (qubits)

Natural atom



Artificial atom



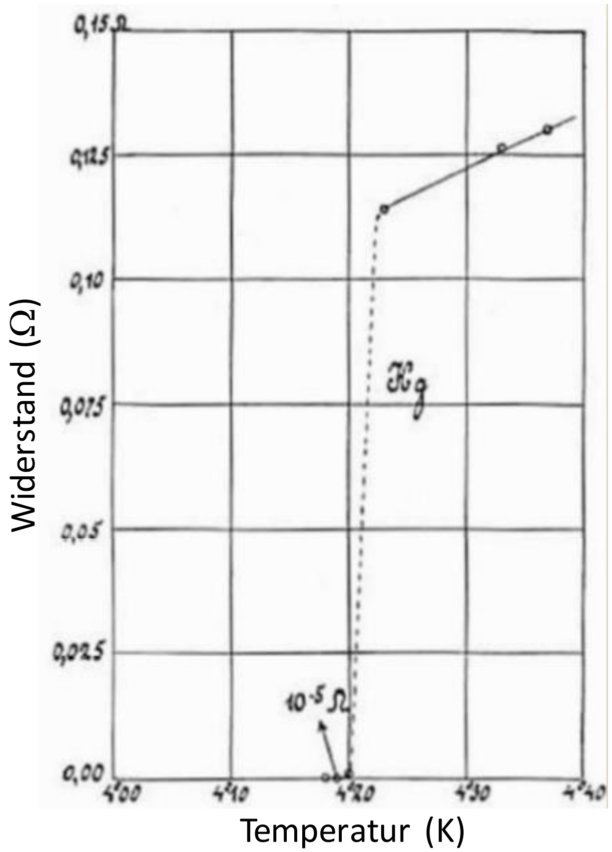
What we like about artificial atoms

- on chip
- fully controllable
- tunable
- strong coupling
- can explore regimes that are not found in natural atoms
- good candidates for new quantum technologies

Applications in

- Quantum computing, information processing
- Quantum optics
- Quantum sensors
- Metrology

Superconductivity

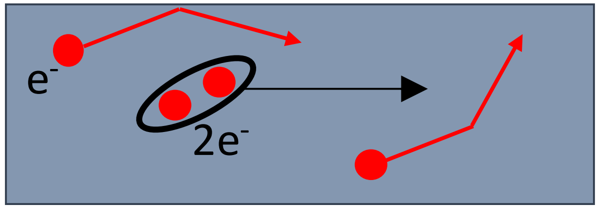


Kammerlingh Onnes, 26 Oktober, 1911

Physics Today, September 2010

More than 100 year old phenomenon

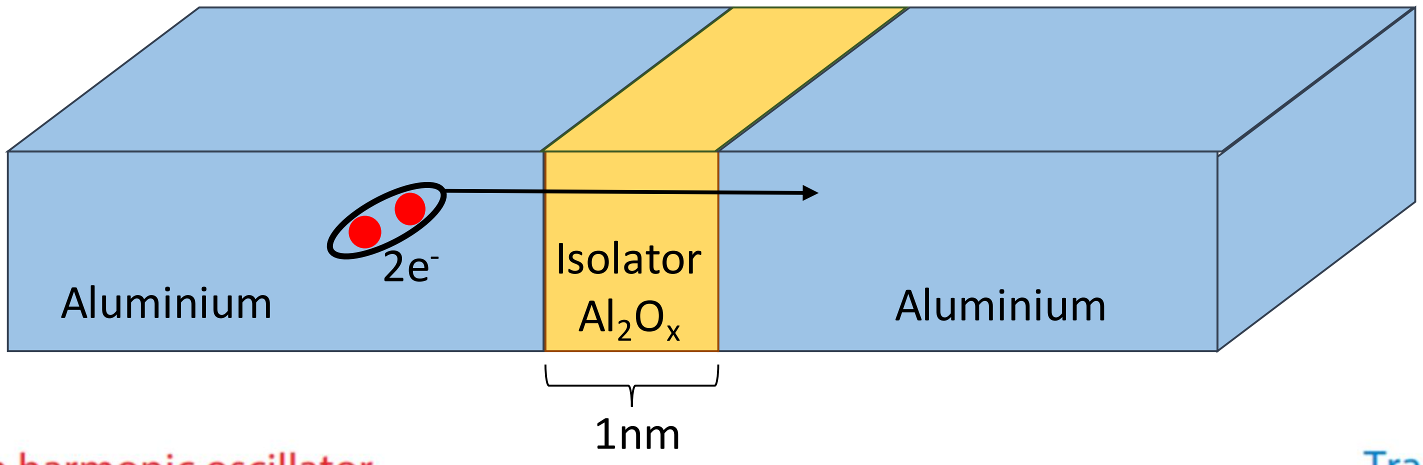
Electrons pair up to Cooper pairs
=> No resistance for current

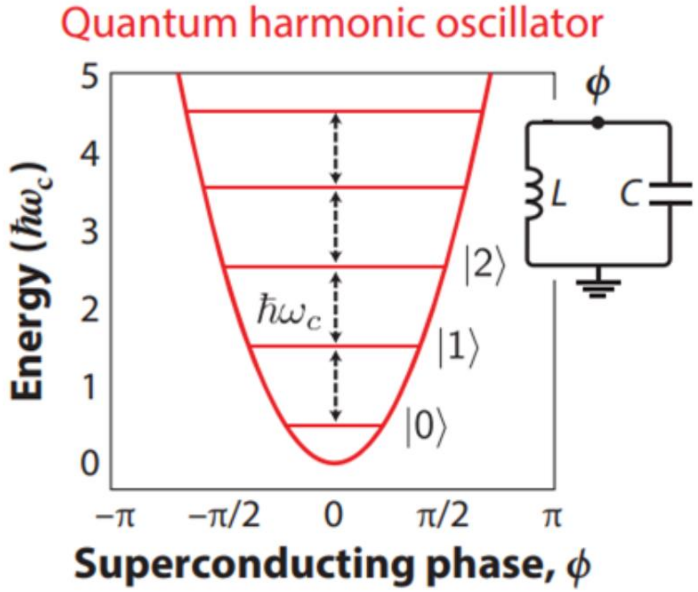


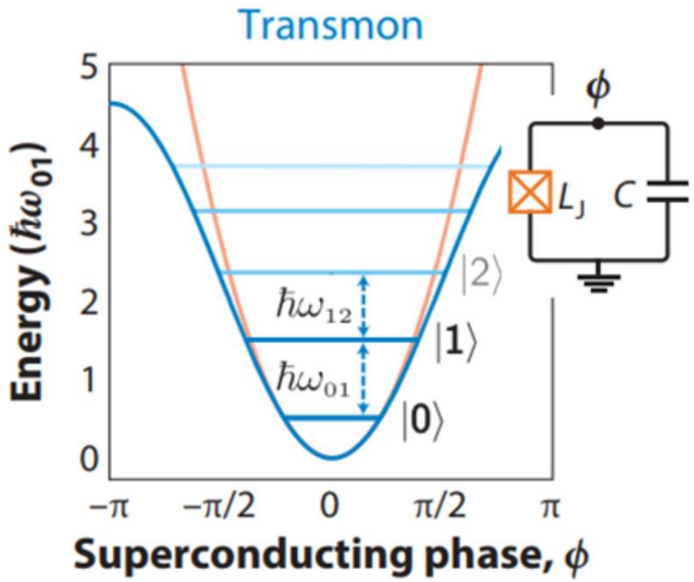
Aluminium, Niobium, Mercury …

Temperature < 1 K

Josephson Contact & Qubit Circuit

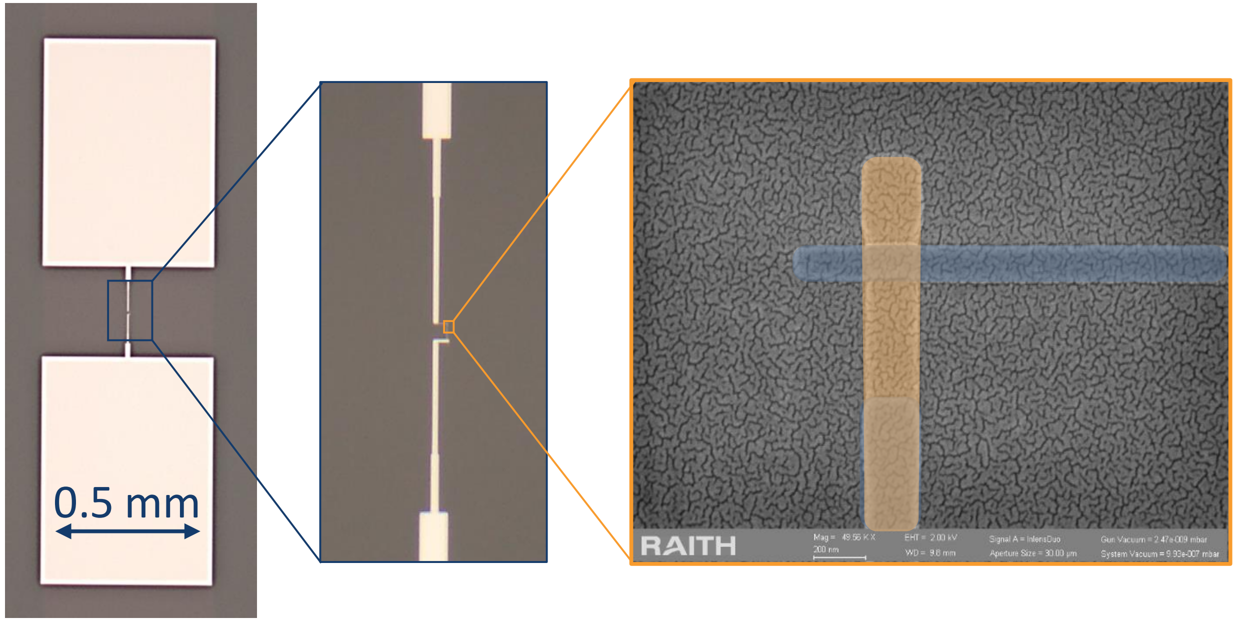






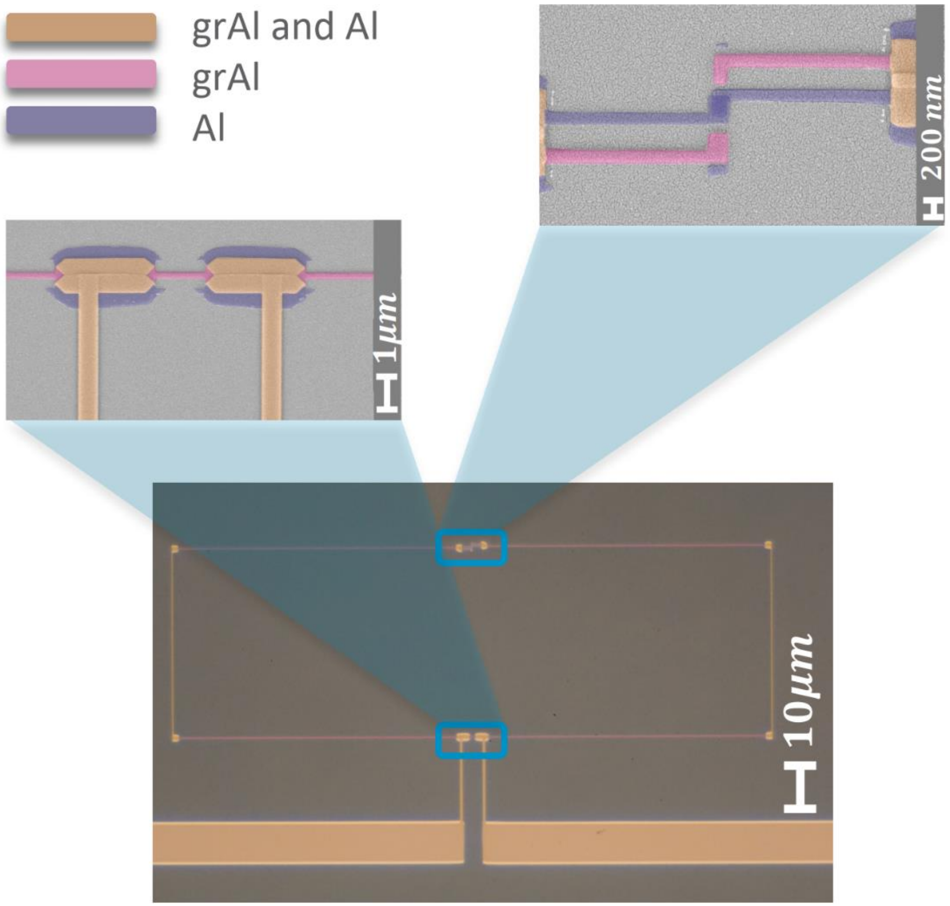
Superconducting Qubit‘s in Innsbruck

Transmon



Yale, MIT, IBM, Google, Saclay…

Fluxonium



Yale, KIT, Amazon…

How do you build a qubit - cleanroom

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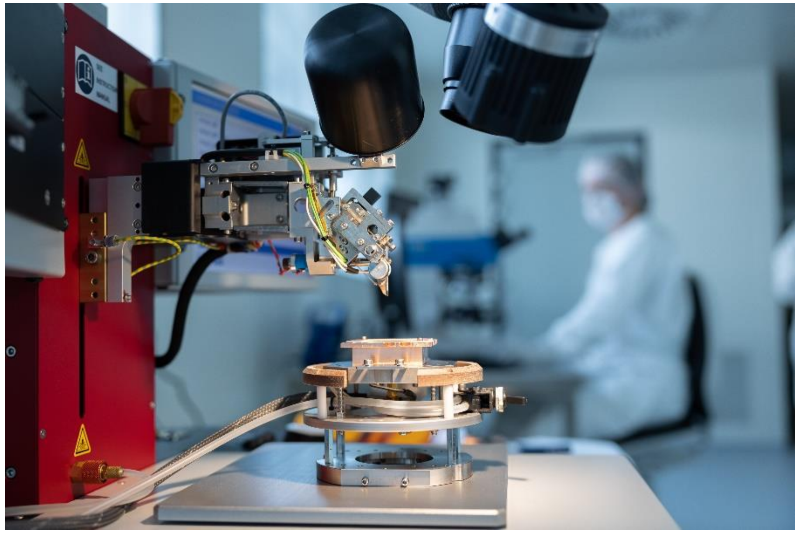

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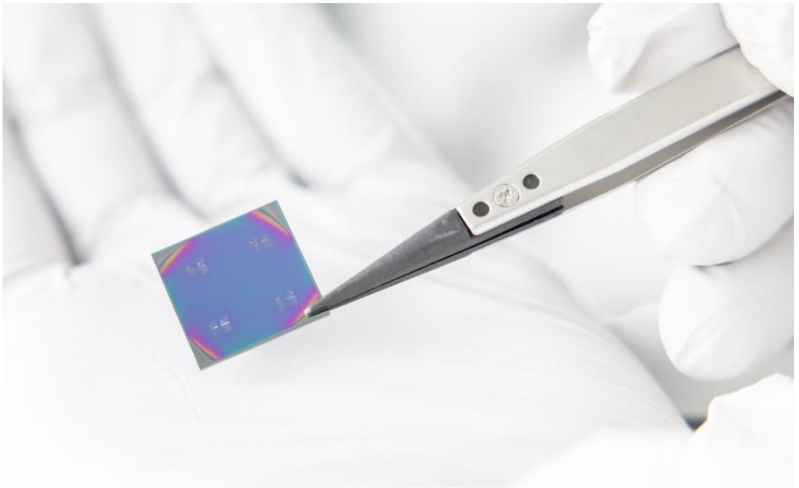
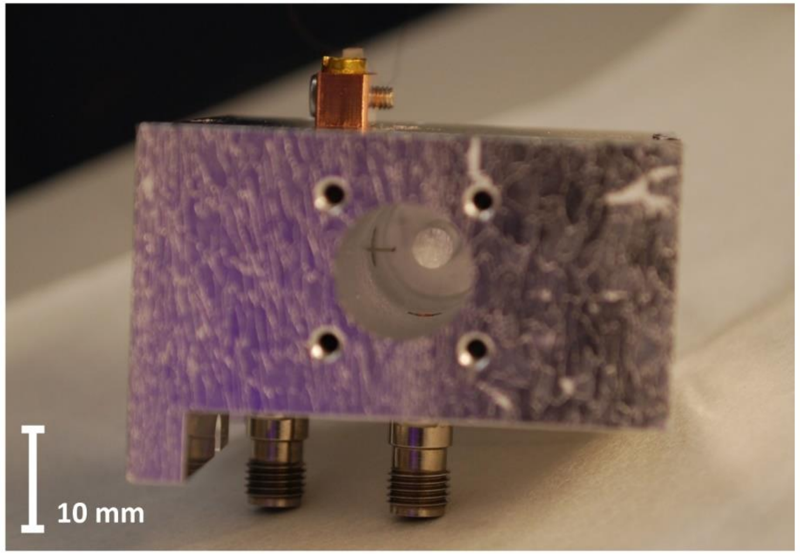
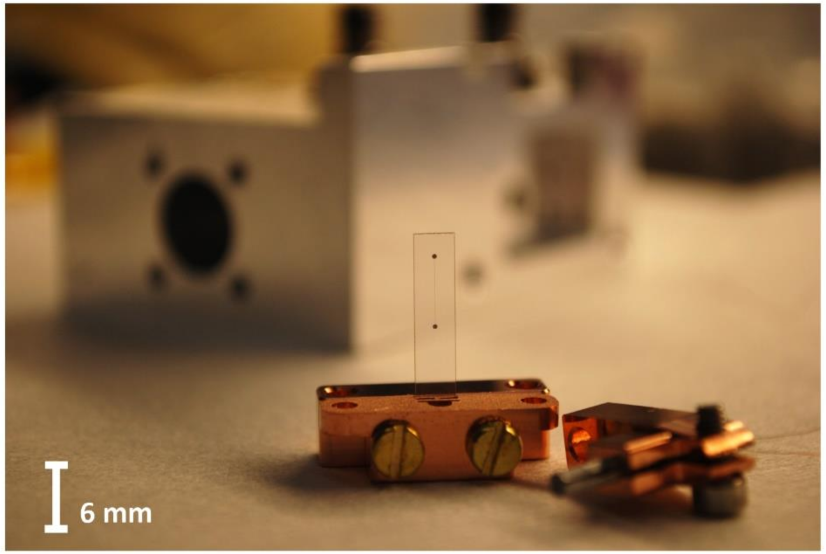


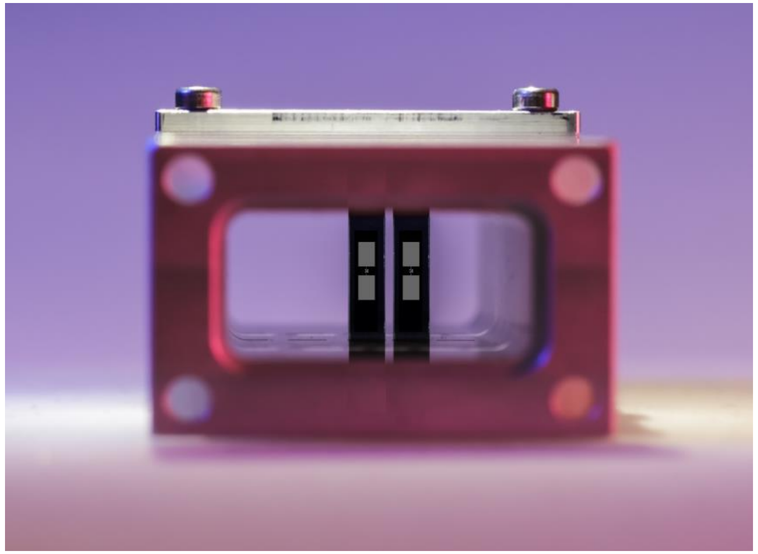
ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

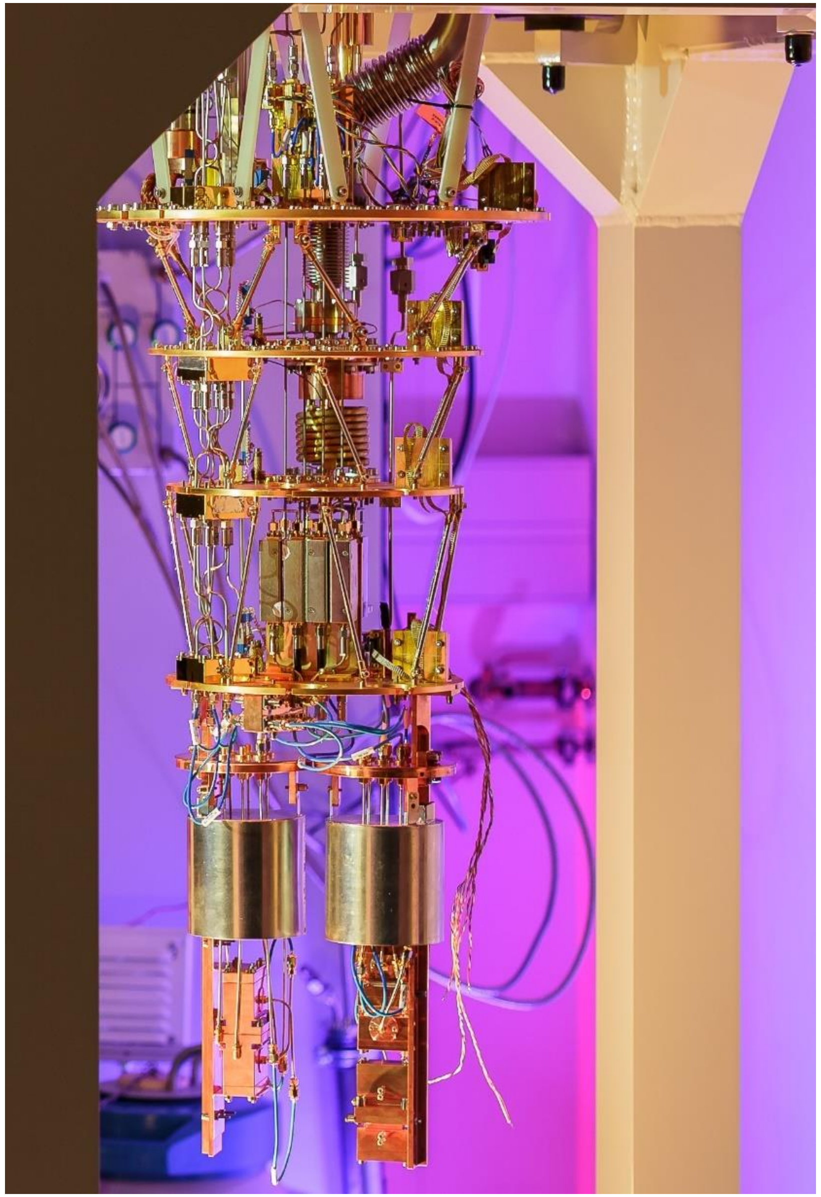
IQI

Experimental Setups & Cryostat









Master Thesis: from Theory to Experiment

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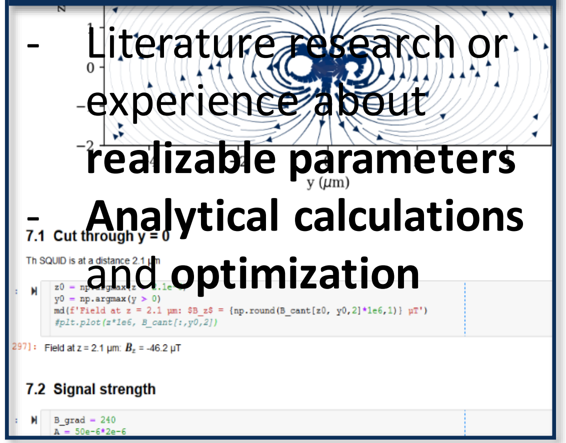
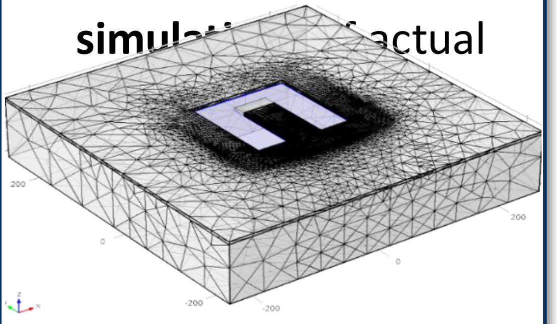
Parameter Study



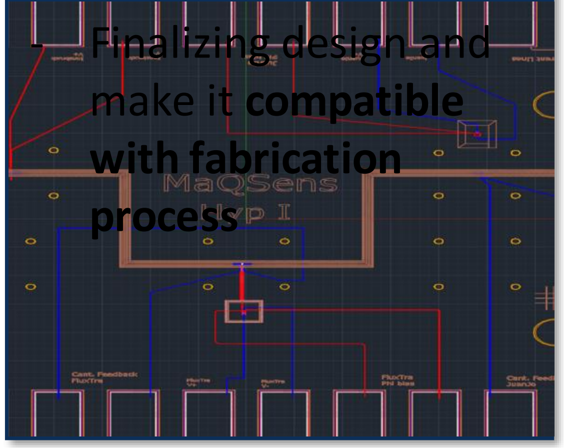
- Literature research or experience about **realizable parameters**
- **Analytical calculations** and **optimization**

Simulations



- **Finite element simulation of actual**

Design



- Finalizing design and make it **compatible with fabrication process**

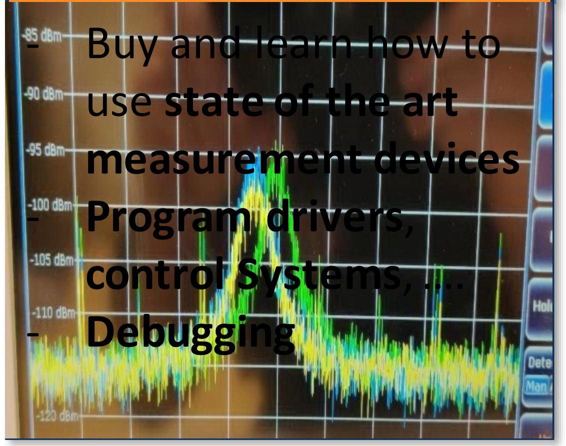
Sample Fabrication

- **Fabricate sample** yourself
- Or **coordinate with collaborators**

Experimental Setup

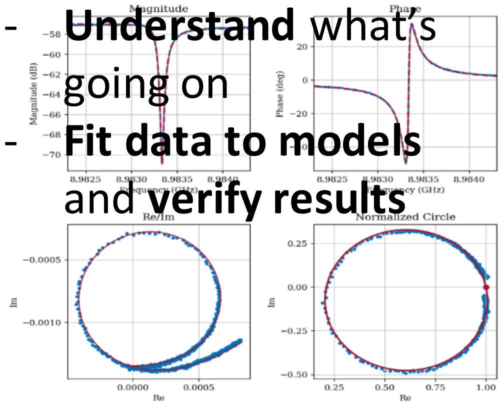
- **Design** sample holder/boxes/shields
- **Coordinate** with mechanical workshop
- **Do it yourself** (lathe, mill, drill, etc.)
- Wire bonding, cryostat….

Measurements



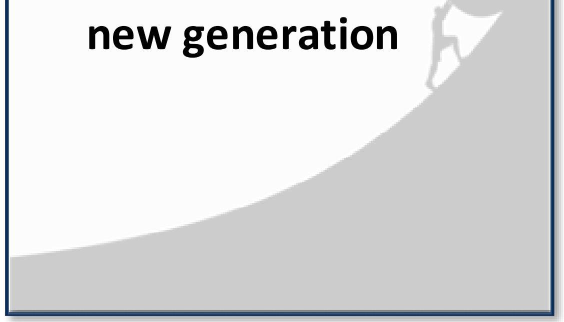
- Buy and learn how to use **state of the art measurement devices**
- **Program drivers, control Systems**, ….
- **Debugging**

Data Analysis



- **Understand** what's going on
- **Fit data to models** and **verify results**

Start again



- If experiment fails -> **Improve** and **start a new generation**

Opportunities in 2022

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BSc projects

- **Superconducting qubit characterisation**
  - Measure coherence times & temperature
  - Understand coherence limitations
  - Need to sign up for "Fortgeschrittenes Praktikum B Optik"!
- **How does a superconducting quantum processor architecture work?**
  - Literature review
- **Multiple thesis possible per topic**

MSc projects

- **Design, build and characterize microwave filters for superconducting qubits**
  - Microwave design and simulation
  - Build mechanical and electrical setup
  - Characterize qubit performance
- **Couple a superconducting high coherence cavity to a mechanical oscillator to cool the mechanics to the ground state**
  - Understand theory
  - Build setup
  - Characterize setup parameters and performance

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Quantum Circuits Group Innsbruck

Join us ☺

Contact

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Gerhard Kirchmair

- Office: IQOQI South (3^{rd} floor)
- Email: gerhard.kirchmair@uibk.ac.at
- Phone: +43 512 507 4760
- www: https://iqoqi.at/_groups/en/group-page-kirchmair

Filip
Hudek

Julian
Daser

Christian
Schlager

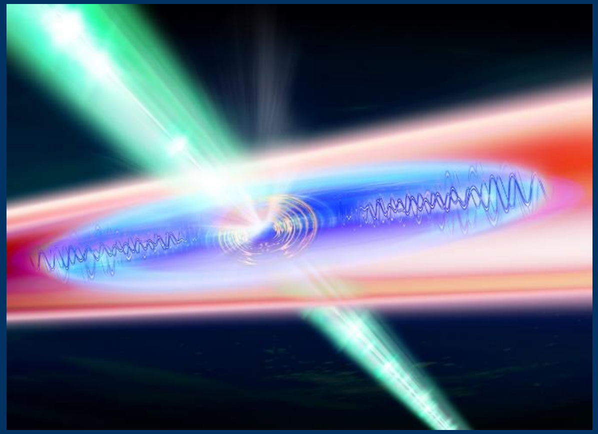
Teresa
Hönigl-Decrinis

Ultrakalte Quantenmaterie

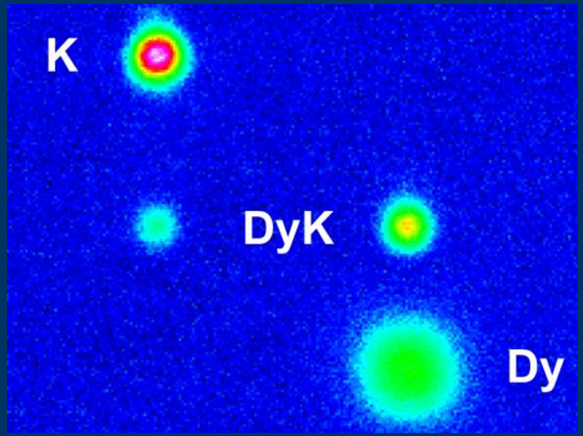
- Supertiefe Abkühlung von atomaren Gasen durch Laserkühlung und Verdampfungskühlung -> Temperaturen im Nanokelvin-Bereich
- Quantenphänomene dominieren und führen zu neuartigen Materiezuständen (Bose-Einstein-Kondensate, suprafluide Fermi-Gase, ...)
- Wir interessieren uns für die grundlegenden Eigenschaften als Modell-Systeme („Quantensimulatoren“) für Vielteilchenphysik in kondensierter Materie

Rudi Grimm

Quasiteilchen
im Fermi-See



Schallausbreitung
im superfluiden Fermi-Gas



Molekülbildung
in Quantengasgemischen

Emil Kirilov

und Teams in drei Laboren

Lernziele

- erster Kontakt mit „echter“ wissenschaftlicher Arbeit
- professioneller und methodisch korrekter Zugang
- verständliche schriftliche und mündliche Darstellung
- weitgehend selbständiges Arbeiten
  im vorgegebenen Zeitrahmen

Lernziele

- erster Kontakt mit „echter“ wissenschaftlicher Arbeit
  - professioneller und methodisch korrekter Zugang
    - verständliche schriftliche und mündliche Darstellung
      - weitgehend selbständiges Arbeiten im vorgegebenen Zeitrahmen

am Beispiel aus einem Spezialgebiet der Physik:
BA-Thema

zur Vorbereitung auf zukünftiges Masterstudium
wissenschaftsgeleitetes Arbeiten

Bachelorarbeit: Literatur oder Labor?

10 ECTS ist leider sehr wenig für die Lernziele:

Zeit reicht oft nur für Literaturstudien, Verfassen der Arbeit,
Erstellen der abschließenden Präsentation

praktische Arbeit (Labor, Computersim., Modellrechnungen) ?

Bachelorarbeit: Literatur oder Labor?

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Zeit reicht oft nur für Literaturstudien, Verfassen der Arbeit, Erstellen der abschließenden Präsentation

praktische Arbeit (Labor, Computersim., Modellrechnungen) ?

Möglichkeiten

- Literaturarbeit mit „Laborwoche“ (10 ECTS)
- Experimentelle BA (10 ECTS)
- Literaturarbeit und separates Laborpraktikum (10+5 ECTS)
- Literaturarbeit in Kombination mit Laborpraktikum (10+5 ECTS)

Laborpraktikum
LV704??? PR „Spezielles Fortgeschrittenenpraktikum B: Optik“ (aus Masterstudium)

Themenbeispiel Literaturarbeit

Continuous Bose–Einstein condensation

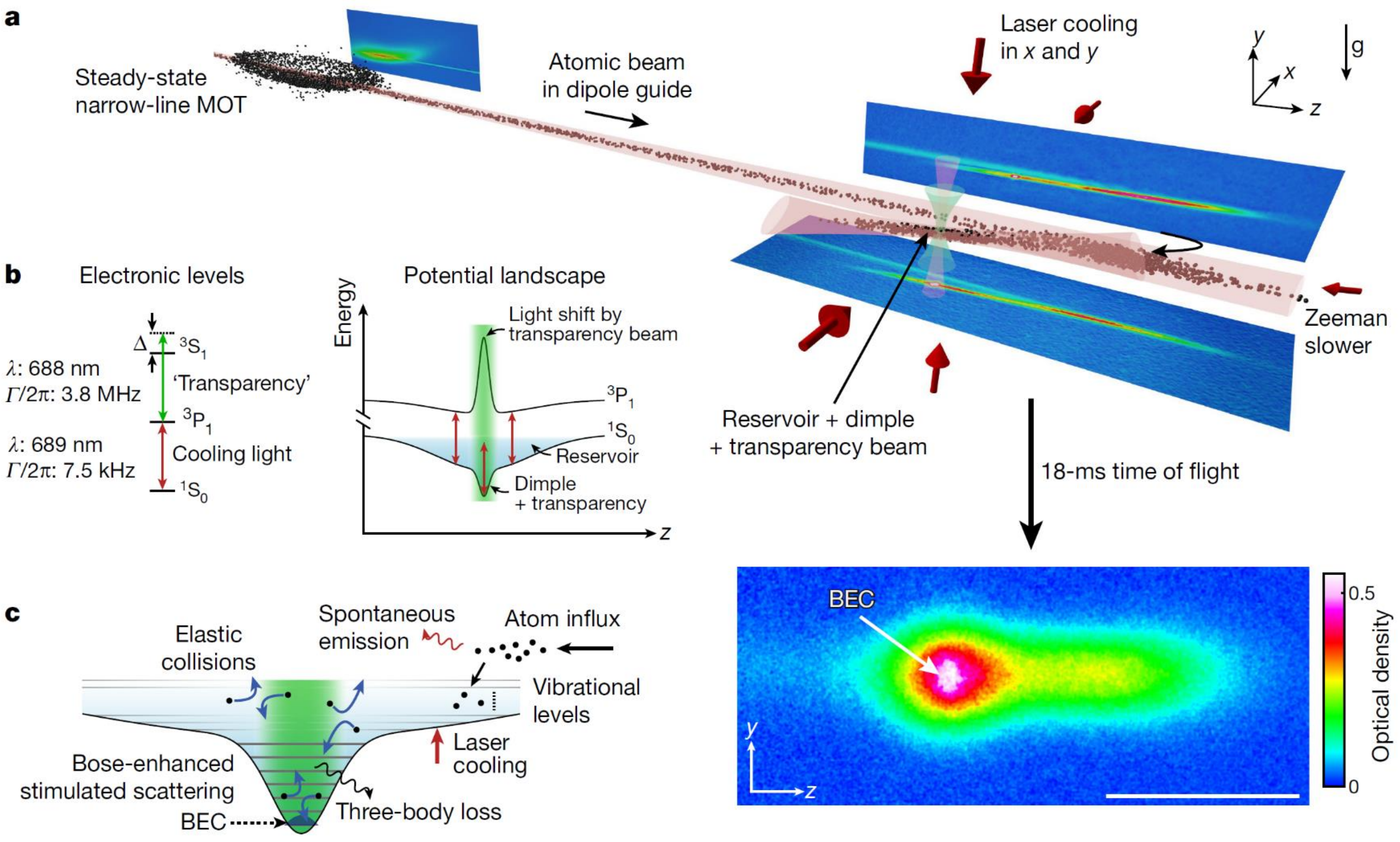
Nature **606**, 683 (2022)

https://doi.org/10.1038/s41586-022-04731-z

Received: 15 September 2021

Chun-Chia Chen[1], Rodrigo González Escudero[1], Jiří Minář[2,3], Benjamin Pasquiou[1,3], Shayne Bennetts[1,3] & Florian Schreck[1,3]

University of Amsterdam

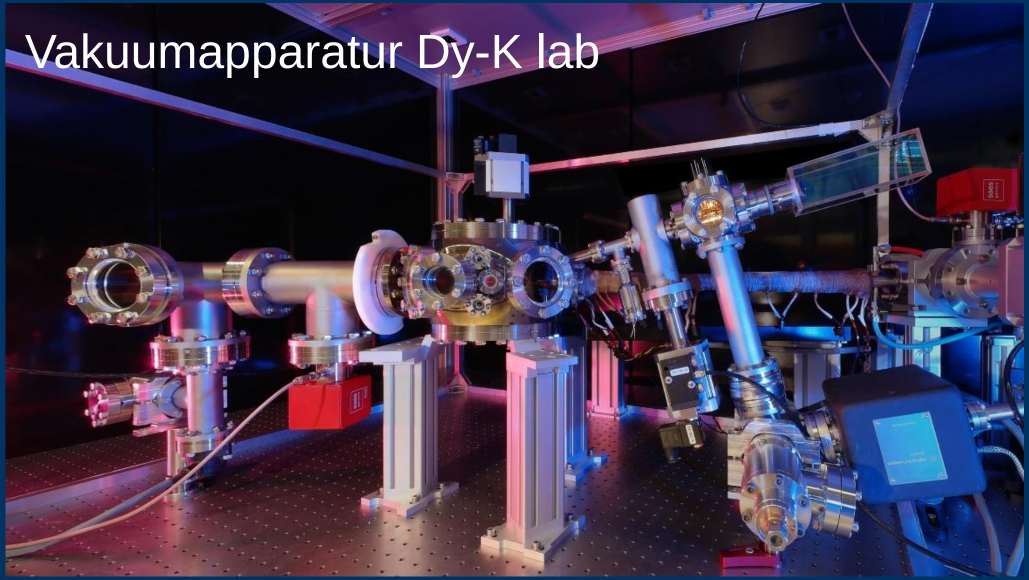


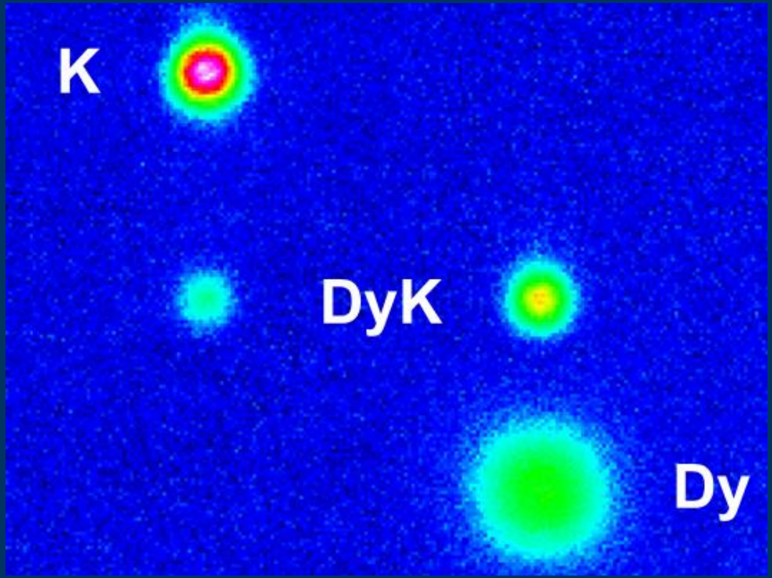
Erstmalige Realisierung eines kontinuierlichen „Atomlasers“

ein großer experimenteller Durchbruch mit vielen interessanten und lehrreichen Tricks

mehr Info zu diesem Thema und weiteren Themen

Themenbeispiel: Literaturarbeit mit Laborwoche





System: Gemisch aus ^{161}Dy und ^{40}K

beide Komponenten sind Fermionen,
^{161}Dy^{40}K-Moleküle sind Bosonen
und diese können kondensieren!!!

Wir untersuchen zur Zeit im Labor die
Eigenschaften dieser Moleküle,
<u>eigene Messungen im Rahmen der Laborwoche</u>

mehr Info zu diesem Thema
und weiteren Themen

Forschungsgruppe:

Ultracold Quantum Matter Theory

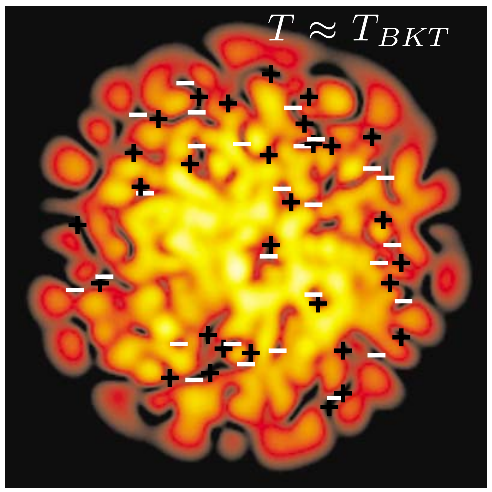
Russell N. Bisset

Russell.Bisset@uibk.ac.at

https://www.uibk.ac.at/exphys/ultracold-theory/index.html.en

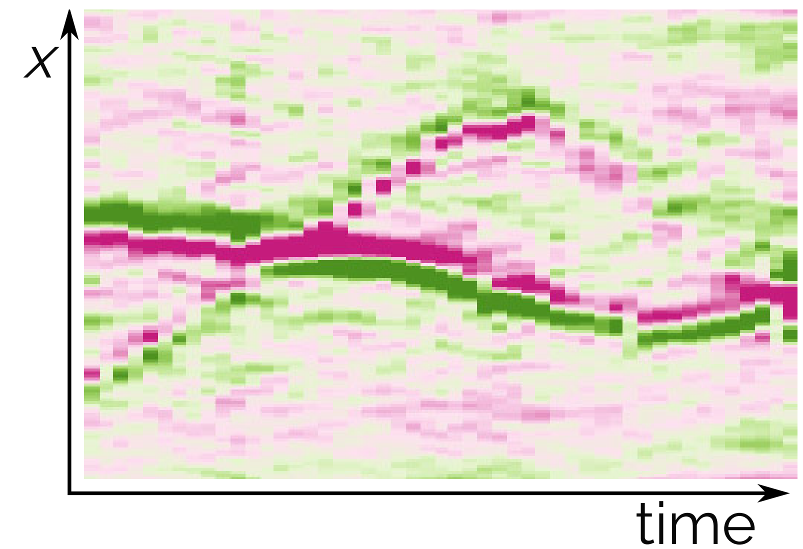
Some of our past work

Thermal 2D superfluids



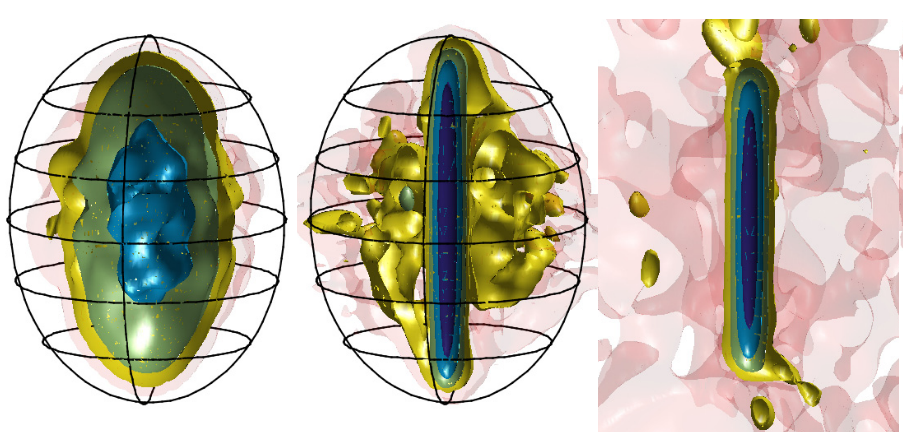
PRA **79**, 033626

Quantum vortex collider



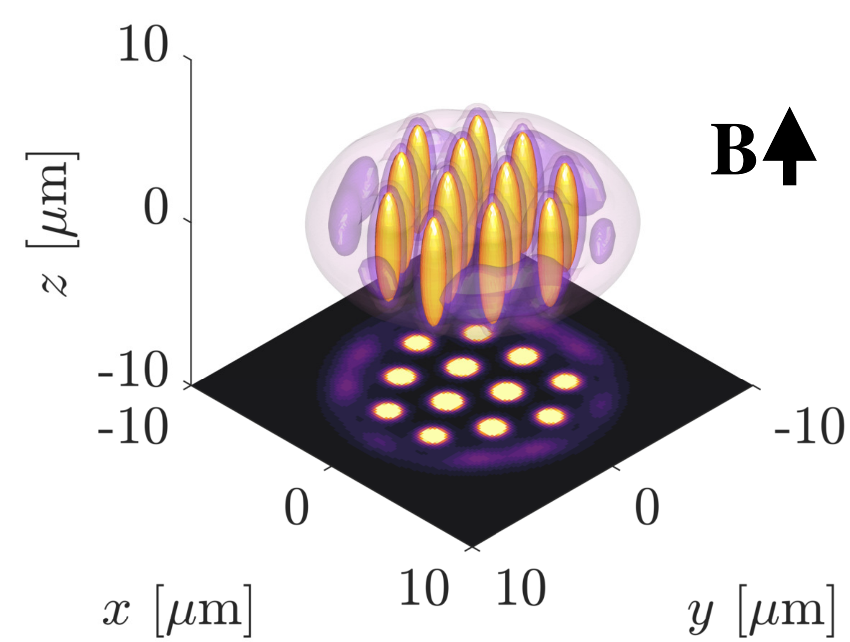
PRX **7**, 021031

Self-bound droplets



PRA **94**, 033619

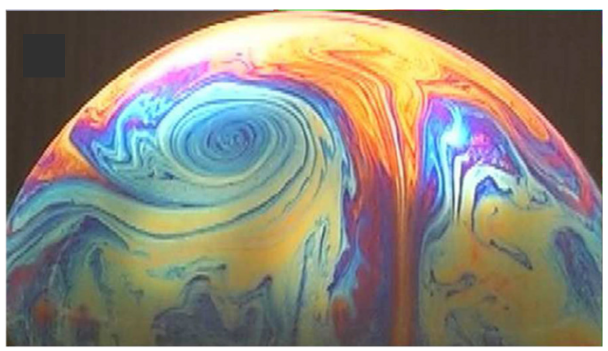
Realization of supersolids

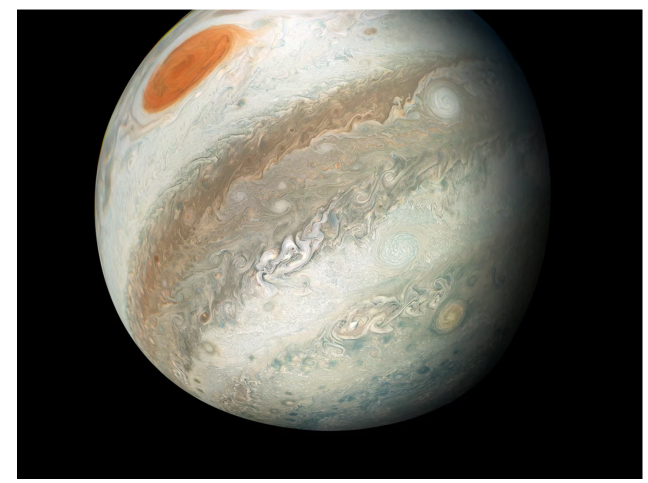


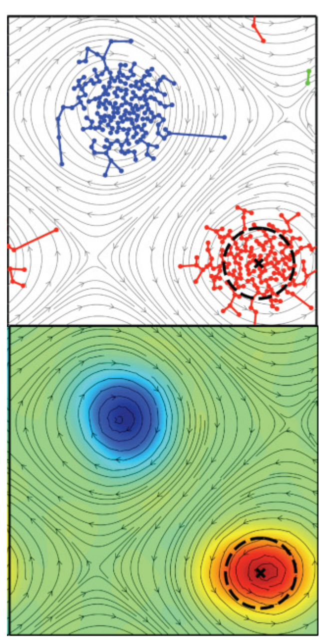
e.g., PRL **122**, 130405,
Nature **596**, 357

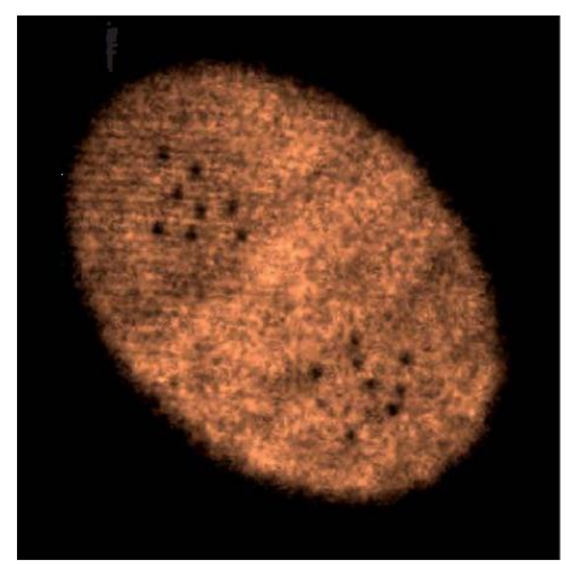
Bachelor thesis project:

Giant quantum vortex clusters









Vortices and turbulence

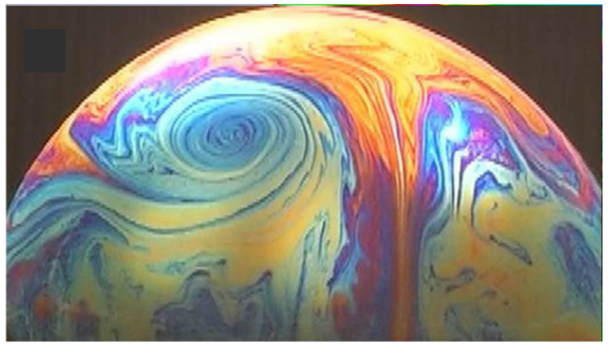
- Large vortices common in turbulent systems, e.g.:

— Soap bubble surfaces

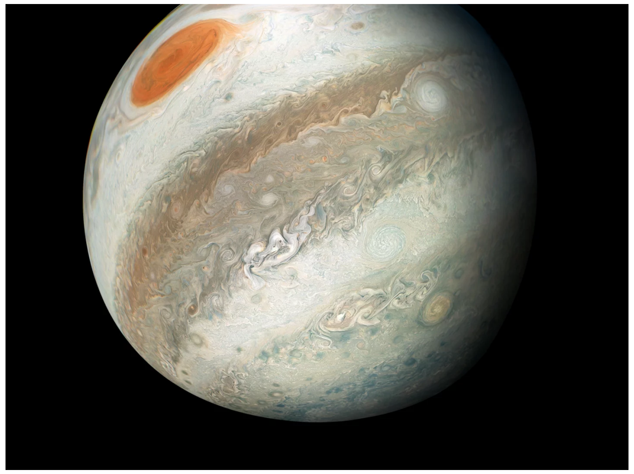
— Plasmas

— Self-gravitating systems

— Atmospheric flows



Soap bubble (Meuel et al.)



Jupiter’s great red spot (NASA)

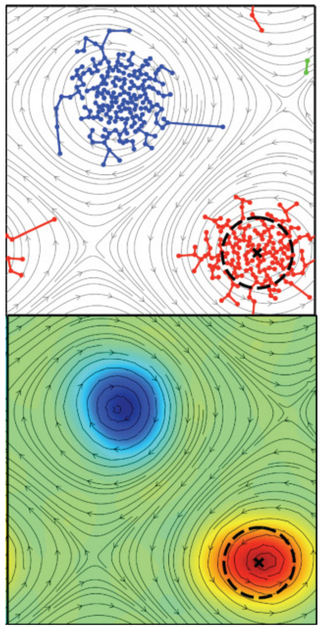
- Understanding of turbulence is still limited
- Onsager proposed a theory based on vortex entropy and temperature

… with giant vortices forming at ultrahot temperatures

Giant quantum vortex clusters

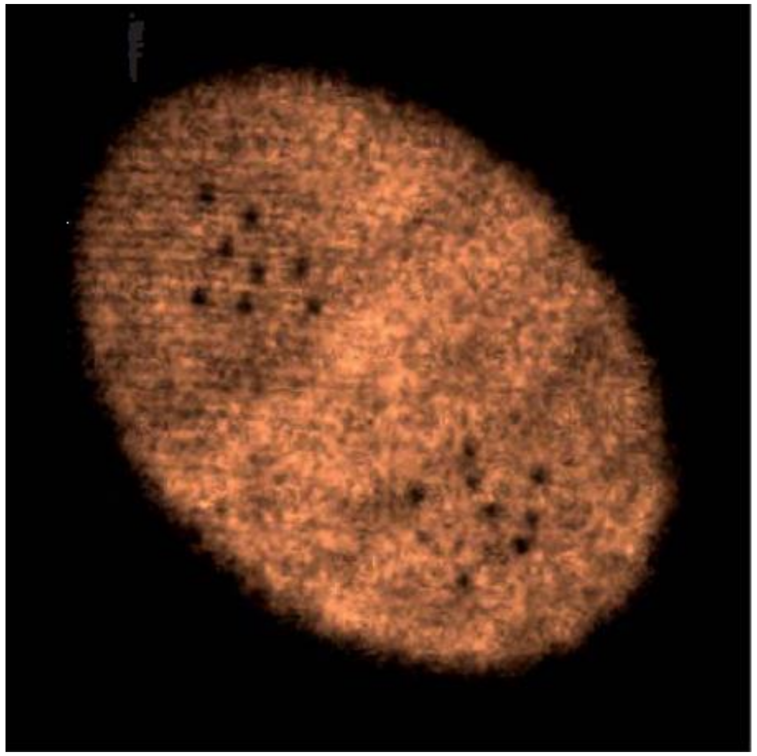
- Ultracold quantum gases may provide an ideal platform to study ultrahot vortex distributions
- This thesis will explore recent theoretical and experimental developments
- Optional component: dynamic simulations

Theory



Reeves et al., PRA **89**, 053631

Experiment



Gauthier et al., Science **364**, 1264 (2019)

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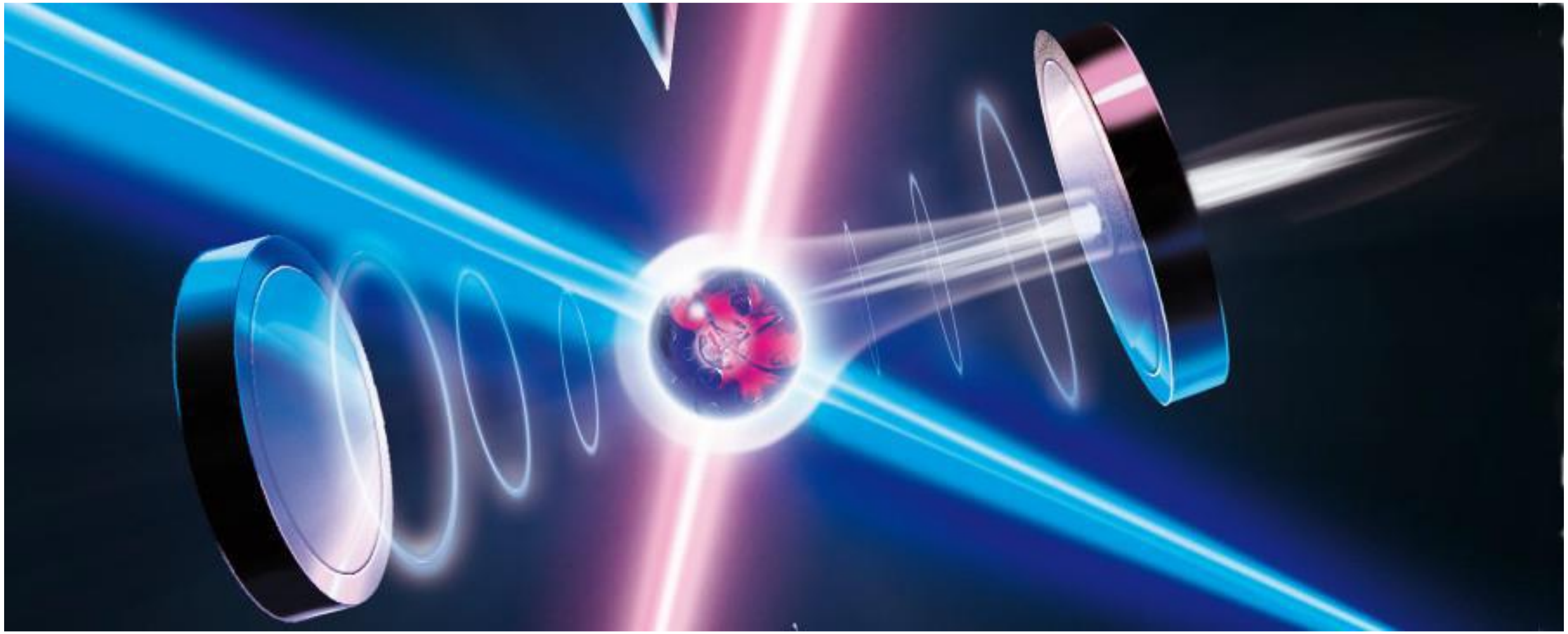
QUANTUM INTERFACES GROUP

Quantum Interfaces Group

AG Northup



Simon Baier (simon.baier@uibk.ac.at)

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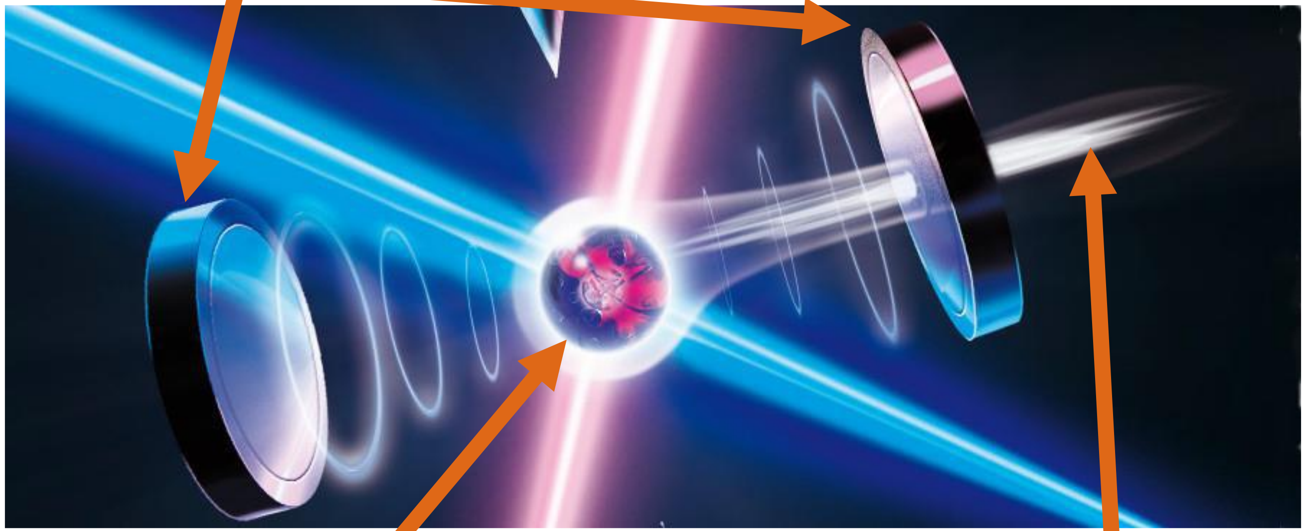
QUANTUM INTERFACES GROUP

Schnittstelle zwischen Licht und Materie

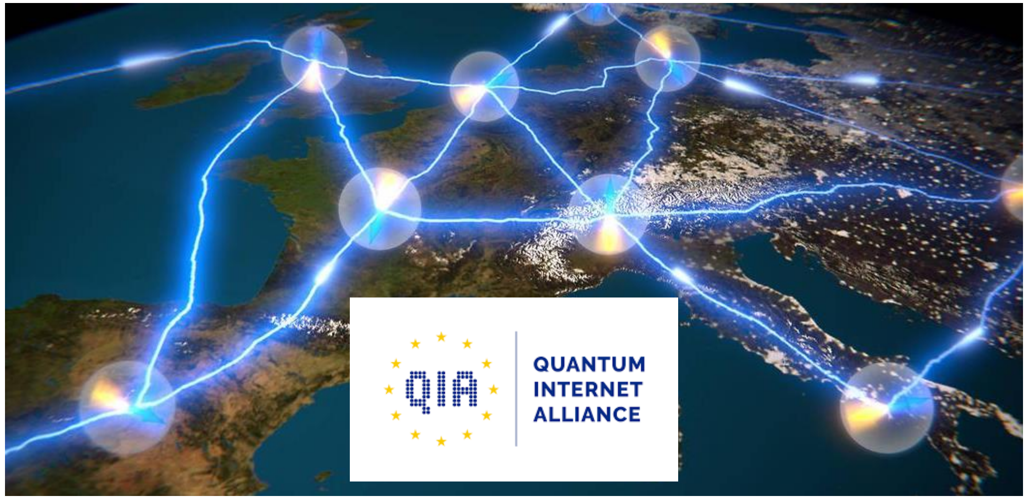
Optischer Resonator als Schnittstelle

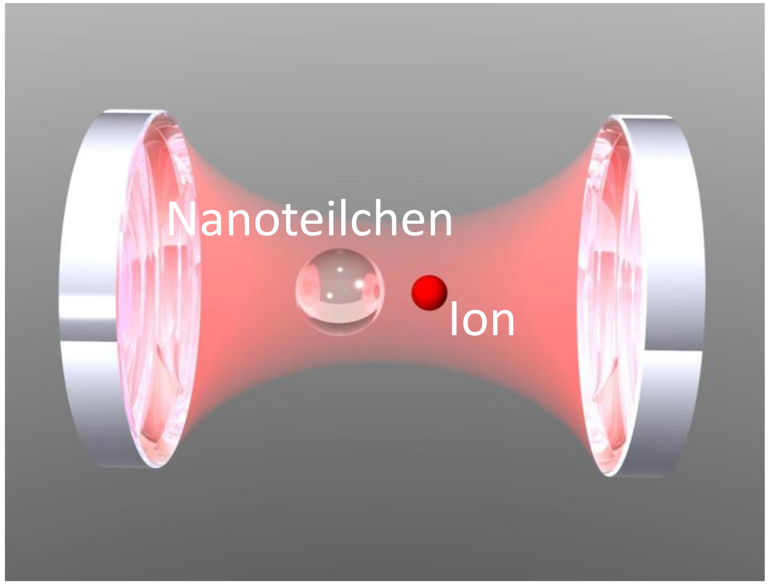


Ion

Photon

Unsere Visionen





Bau und Erforschung von **Quantennetzwerken**
→ Basis für zukünftiges **Quanteninternet**

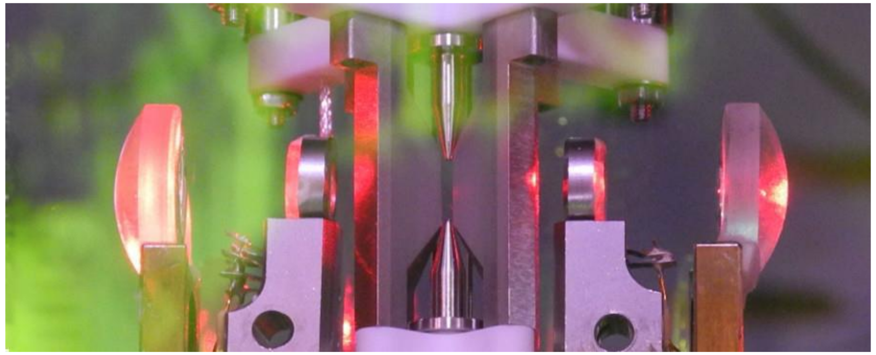
Kopplung von mechanischen Oszillatoren an einzelne Quanten Spins
→ **Erforschung der Quantenmechanik** von massiven Objekten

Gemeinsam mit "Quantum Optics & Spectroscopy"

Bachelorarbeiten

Nur dieses Semester:
KEINE Bachelorarbeiten
(Sabbatical von Prof. Tracy Northup)

Masterarbeiten (Laborarbeit ca. 1 Jahr)



Quantennetzwerke

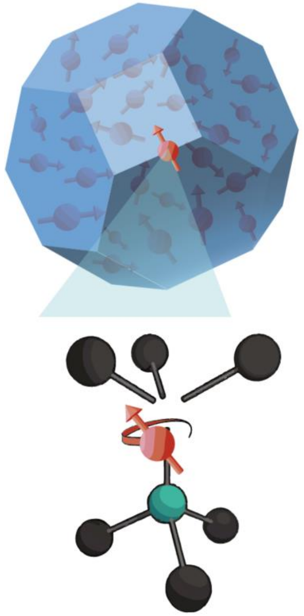
mit Ionen und Photonen

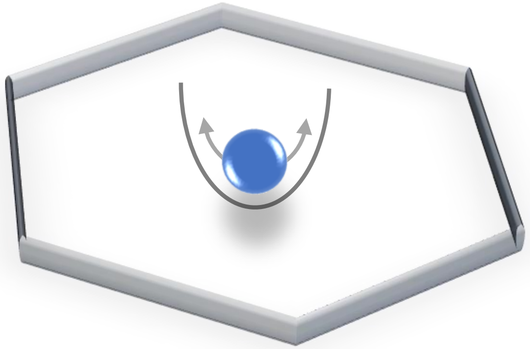
- Kontrolle von mehreren Ionen und Ion-Photon Verschränkung
- Absorption von verschränkten Lichtteilchen

Levitierte Nanodiamanten

Neu

- Stickstoff Fehlstellen als präziser Temperatursensor
- Hybrides System aus Nanodiamanten und Nanoteilchen





Nanoteilchen in Ultrahochvakuum als ultrasensitiver Sensor

- Kette von mehreren Nanoteilchen
- Laserkühlung von Nanoteilchen

universität innsbruck

QUANTUM INTERFACES GROUP

Kontakt für Masterarbeiten:

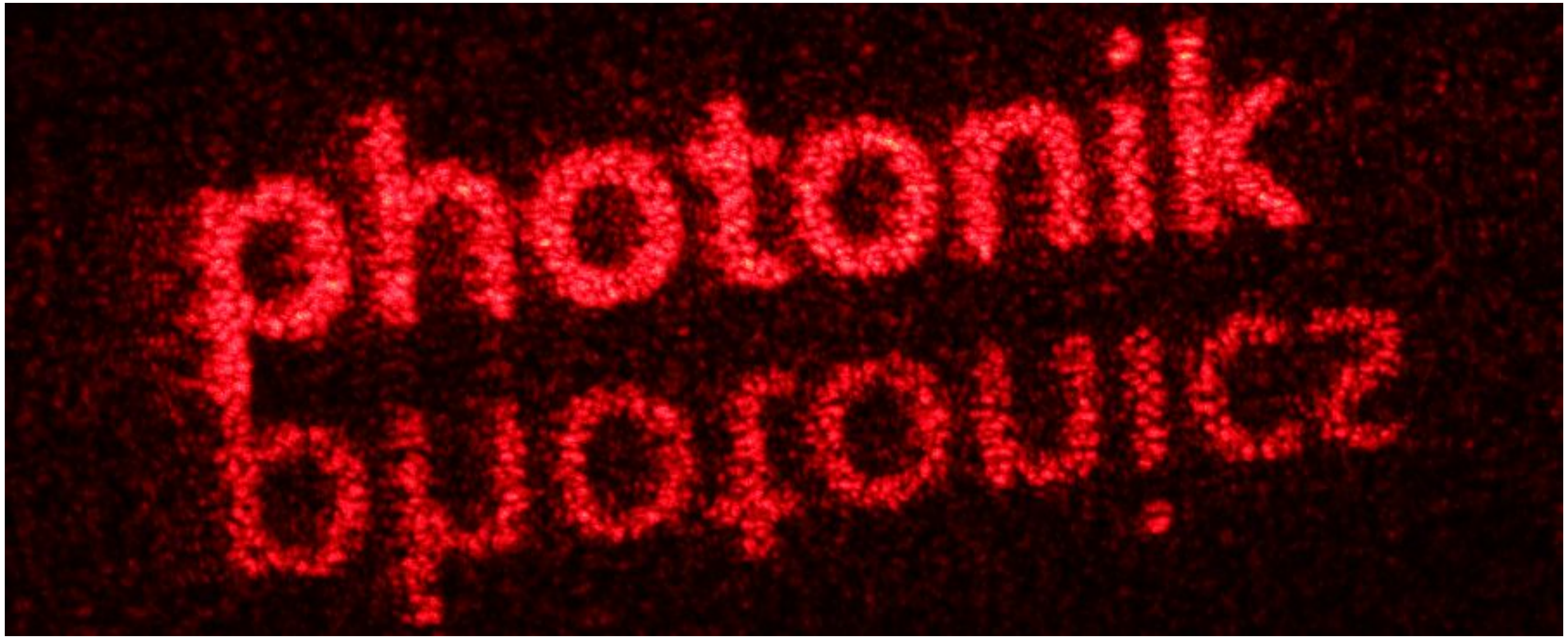
Prof. Tracy Northup (tracy.northup@uibk.ac.at)

Simon Baier (simon.baier@uibk.ac.at)

https://www.uibk.ac.at/exphys/quantum-interfaces/

Theses topics 2023
Photonics

Florian Kappe – 12.01.2023



The group

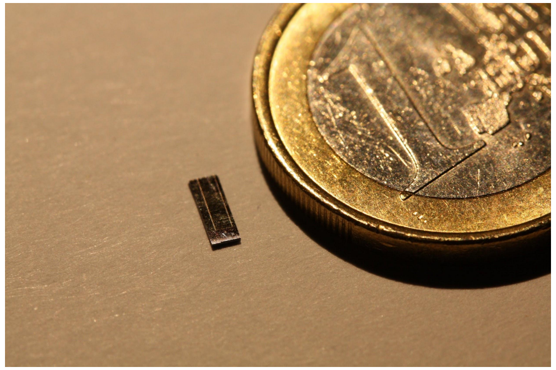
- We work with light (Lasers).
- Generation of quantum light (single photons, entangled states, …).
- Use of nanostructures e.g. waveguides, Quantum Dots
- Supervised by
  Prof. Gregor Weihs.

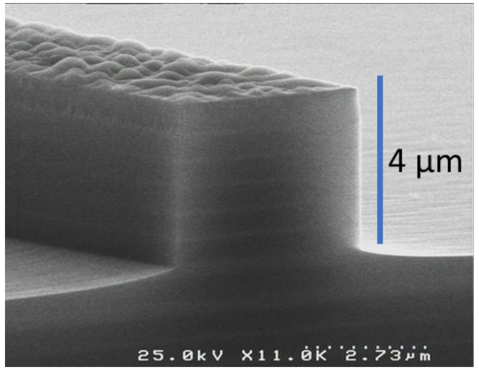
- Three subgroups.

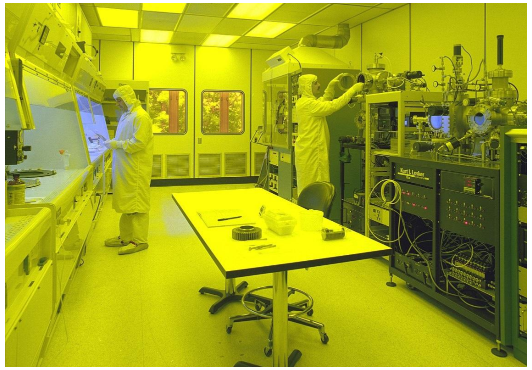
Subgroup: Waveguides

- Research: Semiconductor waveguides.
    - Integrated / on chip optical components.
    - On chip source of entangled photon pairs.
    - Quantum illumination.
    - Quantum Key Distribution (QKD)

Dr. Stefan Frick



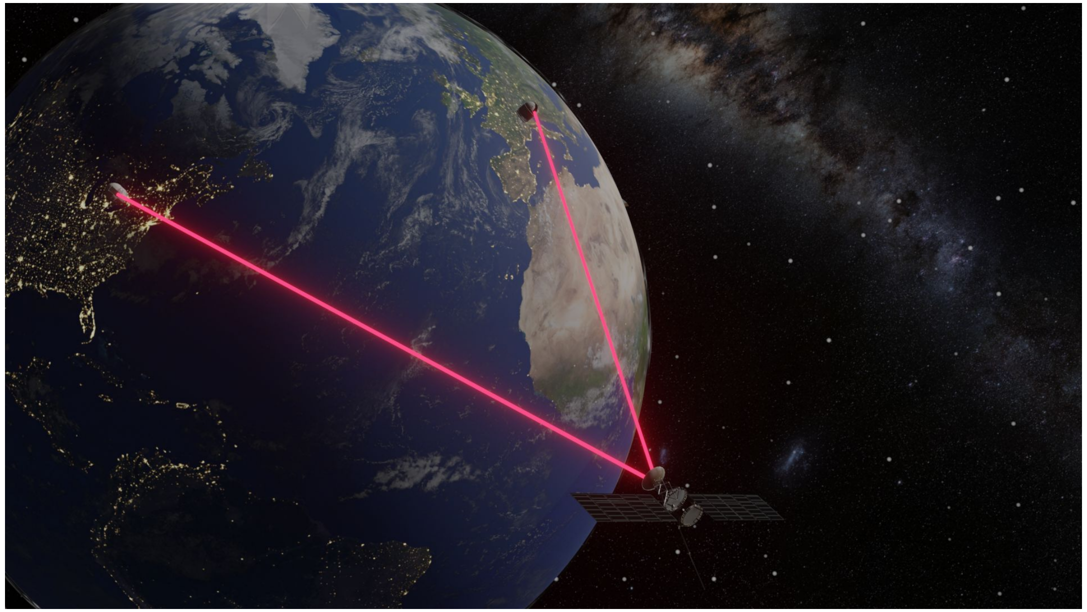




Subgroup: Waveguides

- Available theses topic:
  - Simulating secure key rates in satellite based QKD.
    - Fiber based QKD limited to < 100 km.
    - Orbit, weather, atmosphere are of concern if a satellite is used.

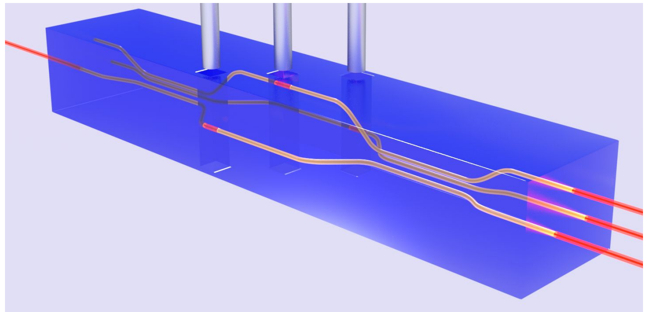
    - Numerical simulations of accessible key rates throughout the year.

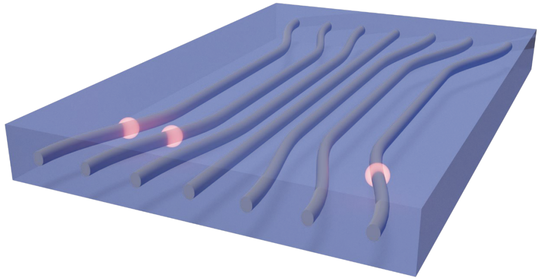


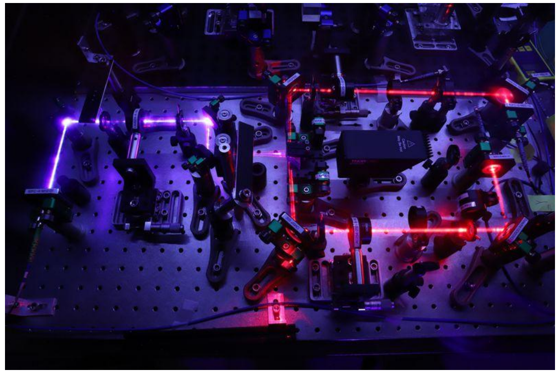
Subgroup: Multipath / Multiparticle

- Research: Foundations of quantum mechanics
  - Interference on >2 path platforms.
  - Multiphoton interference.
  - Engineering of highly indistinguishable photon states.

Dr. Robert Keil







Subgroup: Multipath / Multiparticle

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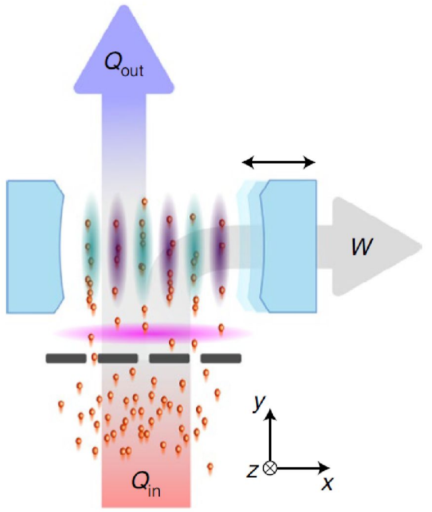
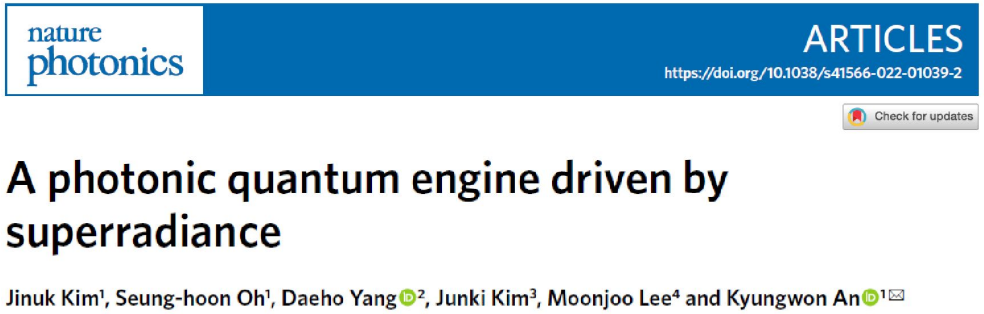
- Available theses topic:
  - Literature study: A photonic quantum engine.
    - Heat engine -> work from heat transport.
    - Classically bounded by Carnot limit.
    - Quantum heat engine can do better [1].



    - Understanding the experiment and the underlying physics.
    - Analyzation of strengths/ weaknesses.
    - (Optional) numerical simulations.


nature photonics

ARTICLES

https://doi.org/10.1038/s41566-022-01039-2

Check for updates

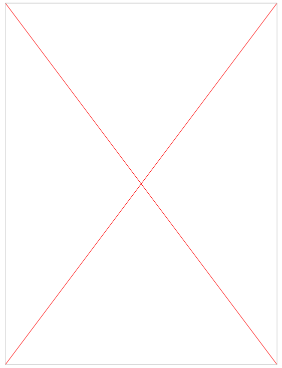
A photonic quantum engine driven by superradiance

Jinuk Kim[1], Seung-hoon Oh[1], Daeho Yang[2], Junki Kim[3], Moonjoo Lee[4] and Kyungwon An[1]

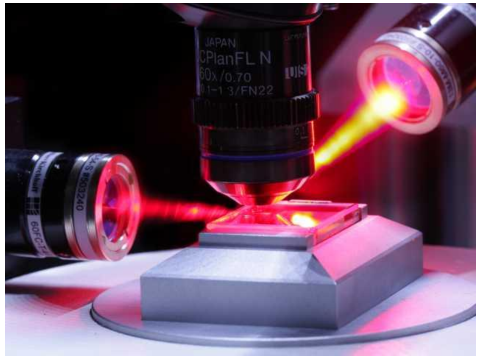
[1] Kim et al., Nat. Phot. **16,** 707 (2022)

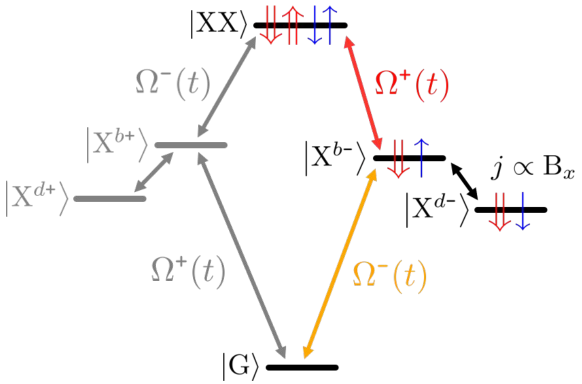
Subgroup: Quantum Dots

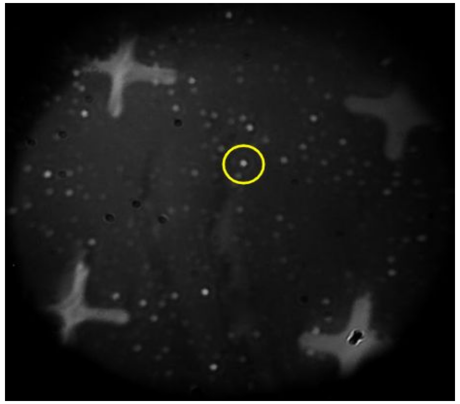
- Research: Semiconductor Quantum Dots (QD)
  - QDs as sources of quantum light.
  - Optical control of quantum states in a QD.
  - Imposing exotic optical pulse-shapes and magnetic fields as control parameters.



Dr. Vikas Remesh

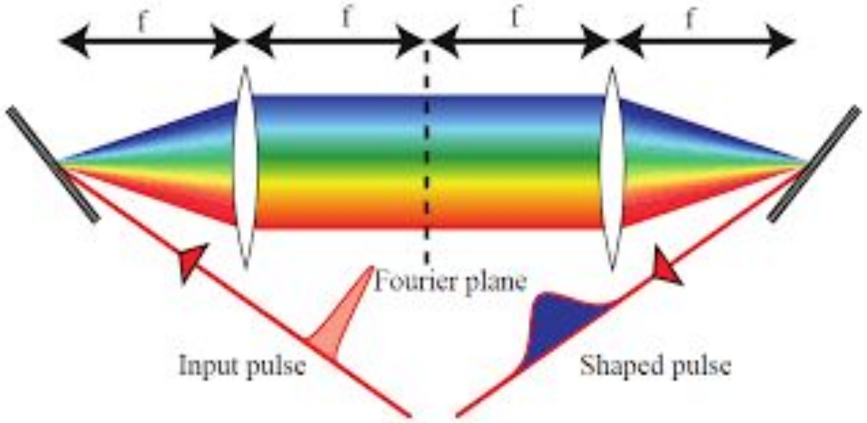






Subgroup: Quantum Dots

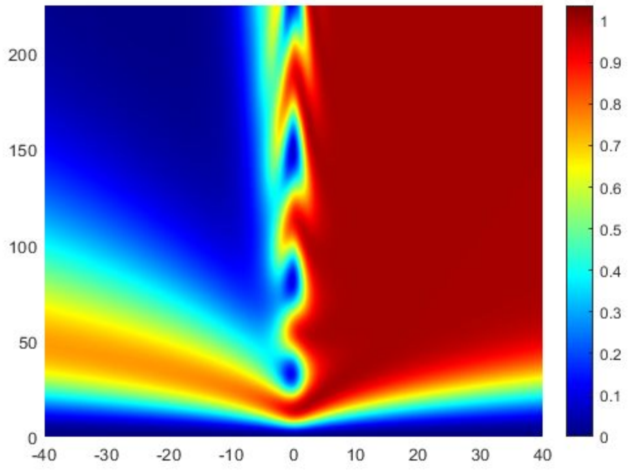
- Available theses topic:
  - Simulating pulse propagation through a pulse shaper [1].
    - Phase-amplitude shaping of laser pulses.
    - Target specific excited states in QDs.
    - Efficient generation of single/entangled photons.

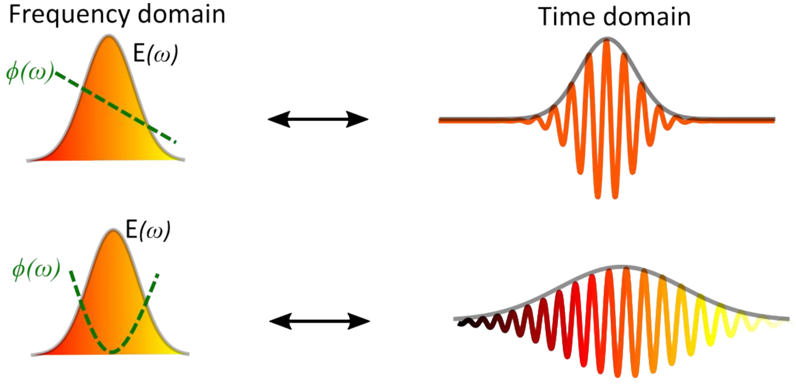


[1] Physical Review A 77.4 (2008)

Subgroup: Quantum Dots

- Available theses topic:
  - Simulating pulse propagation through a pulse shaper [1].
  - Investigating a spectral interference method for pulse characterization [2].
    - Time varying frequency in pulses (chirp) -> hard to measure.
    - Can have experimental part in the lab.

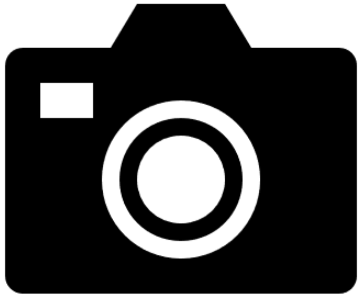




[2] Optics Express 21.11 (2013)

Summary

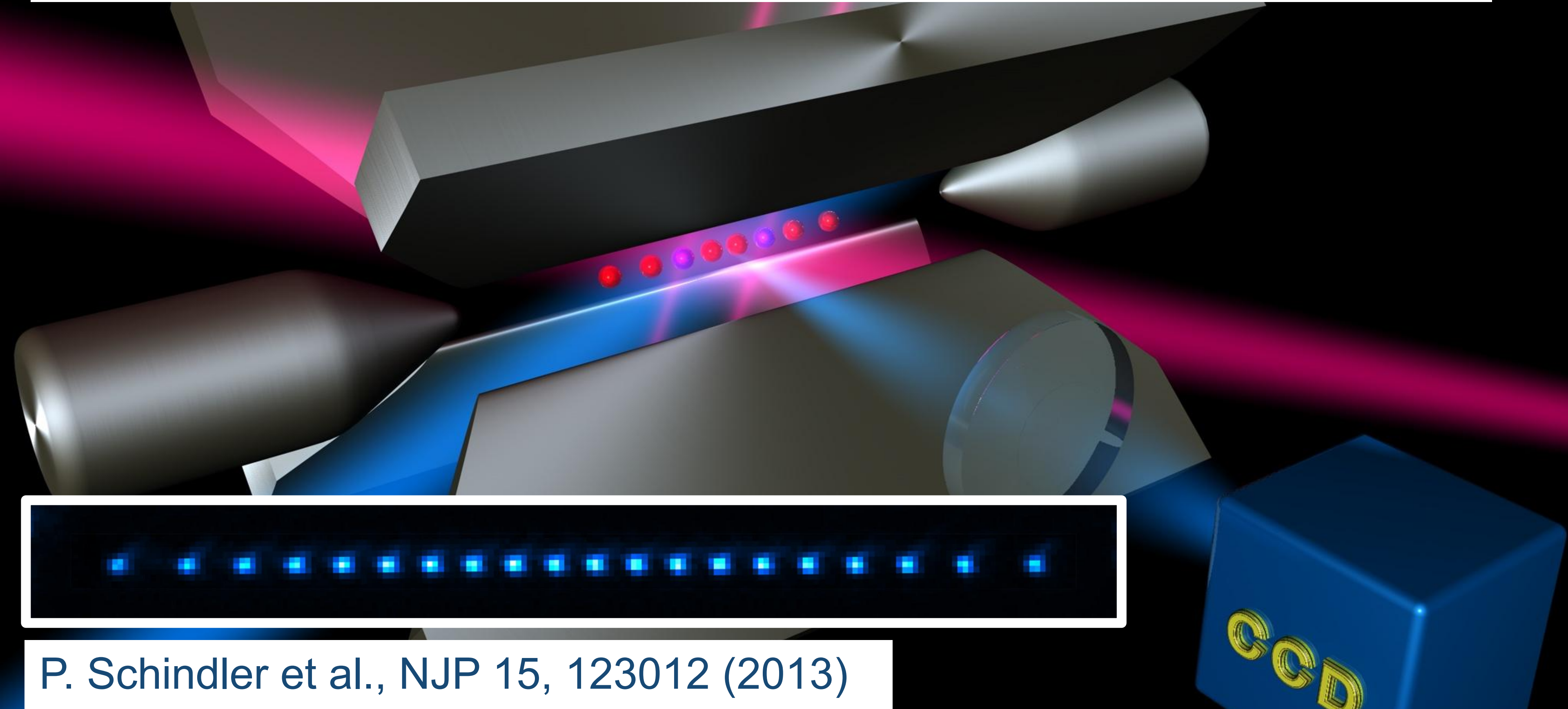
- Applications and generation of quantum states of light.
- Four available BSc topics.
  -> Check the website and write the postdocs.
- Various MSc topics.
  -> Also on website.
- Ask me after this if you want to know more!



Bachelor:

Master:

Quantenoptik & Spektroskopie
Quantum technologies with trapped ions



P. Schindler et al., NJP 15, 123012 (2013)

Ion-trap quantum technologies

Quantum engineering

- Develop a robust quantum hardware platform
- Reduce errors in ion-trap quantum computers
- Implement quantum algorithms

Thomas Monz

High dimensional quantum systems

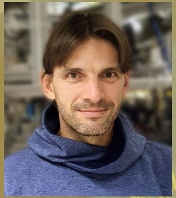
- Encode information more efficiently in multiple levels
- Develop quantum algorithms for qudit systems

Martin Ringbauer

Molecular quantum technologies and scalable systems

- Control single molecular ions
- Encode quantum information in single molecules

- Develop scalable quantum computing architectures



Philipp Schindler

Ion-trap quantum technologies

Bachelor topics:

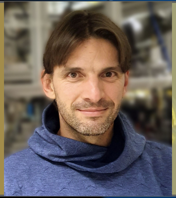
- Quantum computing using trapped electrons, Q. Yu et al, Phys. Rev. A 105, 022420 (2022)
- Photon scattering errors during stimulated Raman transitions in trapped-ion qubits, I. Moore et al, arxiv:2211.00744
- Correlated self-heterodyne method for ultra-low-noise laser linewidth measurements, Z. Yuan et al, Opt. Express 30, 25147-25161 (2022)

Masters topics:

- A high precision laser system for the next generation of quantum computers
- An experimental control system for a scalable ion trap architecture
- Encoding quantum information in a single molecule


Martin Ringbauer


Thomas Monz


Philipp Schindler

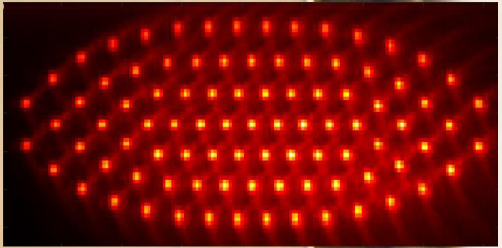
Quantensimulation mit Ionenketten und planaren Ionenkristallen

Bachelorarbeitsthemen:

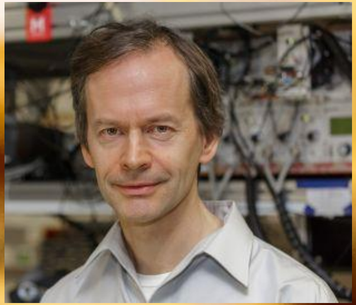
- M. Qiao et al., Observing frustrated quantum magnetism in two-dimensional ion crystals, arXiv:2204.07283
- S. Burd et al., Quantum amplification of boson-mediated interactions, Nature Physics 17, 898 (2021)

Masterarbeitsthemen:

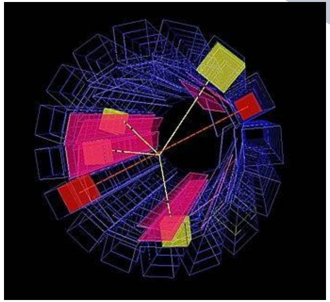
- Laserkühlung und Thermometrie der „in-plane“-Moden planarer Ionenkristalle
- Erzeugung von verschränkten Zuständen in zwei-dimensionalen Ionenkristallen



Christian Roos
christian.roos@uibk.ac.at
Tel. 507-4728



Annihilation detected in ATHENA



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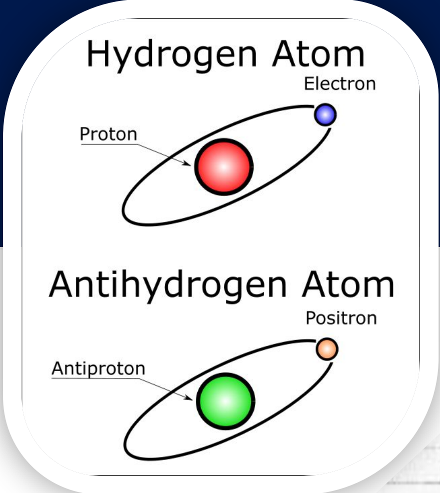
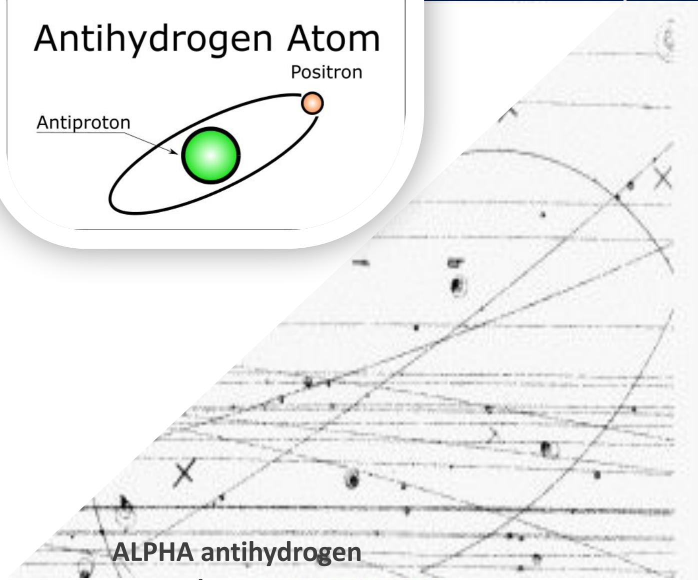
BSc Thesis in antimatter physics





Why is there more matter than antimatter in the universe?

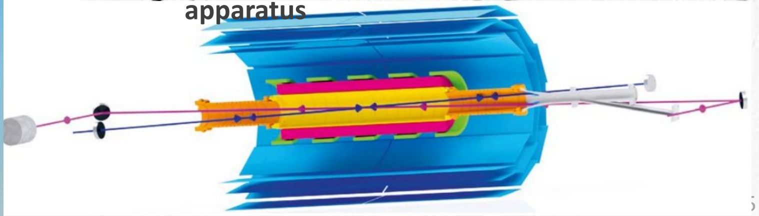
Physicists search for an answer with precision studies on antimatter atoms.

Thesis overview

You will learn about

- synthesis of antimatter atoms in a laboratory,
- laser spectroscopy techniques,
- recent results and currently known limits to the matter-antimatter asymmetry.

ALPHA antihydrogen apparatus



Niels Madsen, Europhysics News **52**.4, 18-21 (2021)

Contact: giovanni.cerchiari@uibk.ac.at

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Rainer Blatt
Giovanni Cerchari
Ben Lanyon
Thomas Monz

Martin Ringbauer
Christian Roos
Philipp Schindler

Contact:
philipp.schindler@uibk.ac.at

www.quantumoptics.at